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Decision-Analytic Support of the
United States Marine Corps' Program Development:
A Guide to the Methodology



Kenneth P. Kuskey
Kathleen A. Waslov
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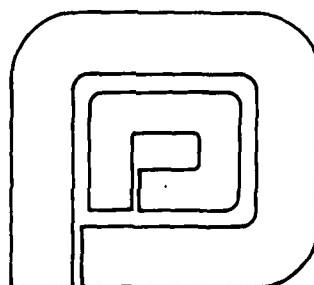
DECISION-ANALYTIC SUPPORT OF THE
UNITED STATES MARINE CORPS' PROGRAM DEVELOPMENT:
A GUIDE TO THE METHODOLOGY

by

Kenneth P. Kuskey, Kathleen A. Waslov, and Dennis M. Buedo

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To strengthen its programming system within the Dod PPBS, the Marine Corps (MC) has recently introduced and tested new, more efficient and reliable techniques for collecting and utilizing the professional judgments of its staff. The new techniques have been developed using the management discipline of decision analysis. The result is a practical, conceptually advanced methodology that has succeeded in developing consensus among the MC staff where other procedures have failed.

This report describes the decision-analytic methodology used by the MC in its programming, not merely overviews. It is suitable as a reference, and it may be used for training.

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ABSTRACT

Within the Department of Defense's (DoD's) planning, programming, and budgeting system (PPBS), the role of programming is to transform defense needs into a time-phased program of affordable and achievable defense activities. This involves decisions on priorities among the potential activities, since not all can be afforded; and such decisions require professional military as well as civilian government judgments about the relative importance of various defense needs. Thus the programming phase of PPBS is the critical step in which professional judgment is matched to resources to create the tangible objectives of the DoD. Programming is complicated by the magnitude of the program (several thousand elements and subelements) and the diversity of the judgments to be utilized.

To strengthen its programming system within the DoD PPBS, the Marine Corps (MC) recently has introduced and tested new, more efficient and reliable techniques for collecting and utilizing the professional judgments of its staff. The new techniques have been developed using the management discipline of decision analysis. The result is a practical, conceptually advanced methodology that has succeeded in developing consensus among the MC staff where other procedures have failed. Based on its successes over the past four years, the MC has brought more and more of its program under the management of its central programming system.

The MC staff continues to search for and find significant new ways to apply decision analysis to its programming system. However, the current strategy and procedures for decision-analytic support of programming have reached a level of sophistication that warrants documentation in the

interests of the continuity of programming. Moreover, such documentation may suggest ideas to the other military services that will help them to refine their own programming systems.

This report describes the decision-analytic methodology used by the MC in its programming system. It provides a working knowledge of the methodology and of MC programming, not merely overviews. It is suitable as a reference, and it may be used for training. Section 1.0 describes the purpose of the report. Section 2.0 describes: (1) the general system of military programming in the Department of Defense; and (2) the MC's approach, including the MC's goals for programming, phases of programming, and the MC purposes that decision-analytic methods serve. Section 3.0 describes the prioritization stage of MC programming, emphasizing the MC's decision-analytic strategy and staff guidelines for prioritization. Section 4.0 describes the decision-analytic methods used by the MC for prioritization, including staff roles and organization, theory, and application procedures. Section 5.0 provides a brief summary and conclusion.

ACKNOWLEDGMENTS

Cameron Peterson, Dennis Buede, and Kenneth Kuskey of Decisions and Designs, Inc. have successively led the development of the technical procedures described in Section 4.0. At Marine Corps headquarters, Colonel Larry Williams and Lieutenant Colonels Kenneth Robinson, John Riley, Kenneth Town, and Marty Lenzini have successively played key roles in the evolution of the programming strategy described in Sections 2.0 and 3.0. Kathleen Waslov has prepared the mathematical description of the technical procedures in Section 4.0.

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DECISION-ANALYTIC SUPPORT OF THE
UNITED STATES MARINE CORPS' PROGRAM DEVELOPMENT:
A GUIDE TO THE METHODOLOGY

1.0 INTRODUCTION

1.1 Purpose

This report describes the decision-analytic methodology used by the Marine Corps (MC) to develop its portion of the Department of the Navy's (DON's) program objectives memorandum (POM).

This report has two companion reports that document a POM data base management system (DBMS).¹ This system supports the MC staff as it collects, prioritizes, and programs the items of the POM using the methodology described here. The three documents form a package that explains the nature of the MC staff's methodology as of November 1980. This package can be used to solicit decision-analytic contractor support for the MC staff's POM development, or to develop such support within the MC staff. In either case, it is assumed that the users of this report have a broad background in the decision sciences. The report indoctrinates these users in the aspects of decision analysis that have been applied to the MC's development of the POM.

¹Waslov, K. A.; Kuskey, K. P., Program Objectives Memorandum-Data Base Management System Users Manual UM-81-1-158 (McLean, Virginia: Decisions and Designs, Inc., May 1981).

Esoda, R. M., Program Objectives Memorandum-Data Base Management System Program Maintenance Manual, UM-81-2-158 (McLean, Virginia: Decisions and Designs, Inc., May 1981).

1.2 Background

The MC POM-development process consists of an annual reassessment and adjustment of the Commandant of the Marine Corps's (CMC's) program for the MC. Over the years, the MC staff's strategy and methods for preparing the MC's POM submission to the DoN have evolved substantially. POM preparation has become the vehicle for a systematic, comprehensive management review of MC missions, manpower, operations, and acquisitions.

A significant factor in the evolution of MC programming has been the introduction of the management discipline of decision analysis. The MC staff first explored the usefulness of decision analysis for POM development in a project sponsored jointly with the Defense Advanced Research Projects Agency (DARPA) in 1977. In each subsequent year the MC staff has obtained contractor support to continue the development and implementation of decision-analytic programming methods. The bibliography in Section 2.4 lists a series of reports through which the evolution of MC POM methodology can be traced. This report describes the current status of the methodology.

The MC staff's application of decision analysis to the POM is distinctive for its twin emphases on the judgmental and group aspects of MC decision making. At root, it is a scheme for finding "wisdom in a multitude of counselors." By dividing the MC staff into working groups with special expertise, eliciting these groups' best collective judgments about program priorities, and then merging their judgments, overall MC priorities emerge. Decision-analytic methods are used to effect this divide-conquer-reunite process. They involve (1) the quantitative representation of the officers' judgments of priority, (2) a "sampling" procedure applied to

the groups to merge their judgments, and (3) a cost-effectiveness analysis based on the quantified judgments of priority.

While the introduction of decision-analytic methods has had a pervasive effect on the process of MC programming, the methods themselves are developed and applied by only a handful of individuals within the Program Coordination Branch (RPP) of the Deputy Chief of Staff for Requirements and Programs (DC/S R&P). RPP has used decision analysis to advance the MC staff consistently towards three major goals:

- (a) A systematic, practical MC-staff process of programming, extending through the full POM cycle from initial program guidance to amended program-decision memorandum, that assists the MC staff to satisfy MC military needs with programs in a compellingly logical way.
- (b) Sound procedures for eliciting, representing, combining, and using the collective professional military judgments of the MC staff to determine program priorities.
- (c) Timeliness, accuracy, and flexibility of programming--plus an audit trail of all judgments of priority--achieved through a specialized decision aid and data base management system that supports the decision-analytic POM methodology.

The MC methodology is a unique application of decision analysis that advances the state of the art for practical resource allocation and programming in large institutions. Besides the MC POM, it has been applied to (1) the U.S. Army POM, (2) the Army's mobility equipment research and development program, (3) the Tactical Air Command's program for night and weather acquisitions, (4) the National Aeronautic

and Space Administration's research program, and (5) commercial strategies for product development. References are found in Section 2.4.

1.3 Plan

Sections 2.0 and 3.0 describe the practical goals, scientific background, and overall logic of the MC's decision-analytic methodology for POM development. Section 4.0 describes the technical procedures for carrying out the methodology. Both sections are written for the reader who needs a working knowledge of the methodology, not just an overview.

2.0 BACKGROUND AND CONCEPTUAL FRAMEWORK

2.1 Introduction

This section describes decision-analytic support in the overall context of MC planning, programming, and budgeting; formulates the MC programming problem from a methodological, resource-allocation perspective; and provides a bibliography of applications and theory.

2.2 The General Context of Decision-Analytic Support

Various broad aspects of the DoD, DoN, and MC planning, programming, and budgeting systems (PPBSs) are important background for designing and applying decision-analytic methods to MC POM development. These are discussed in terms of the federal budgetary system, DoD PPBS, Navy/MC PPBS, and MC PPBS.

2.2.1 Federal budgetary system - All federal expenditures are determined during the federal government's annual budget cycle. Under law, the President's role is to develop and to propose to Congress a unified plan (budget) of expenditures every year, while the role of the Congress is to review this plan, develop alternatives, authorize programs, appropriate funds, and legislate taxes to provide funds. The President's staff for the development of the budget is the Office of Management and Budget (OMB). OMB forms the President's budget from proposals submitted by all the federal agencies, including the defense agencies. The President's proposed budget for defense is a product of the Office of the Secretary of Defense (OSD) and OMB working jointly.

2.2.2 DoD PPBS - To develop a defense budget for the President, OSD manages the development of a joint-service budget through its PPBS. The PPBS is internal to DoD and does not interface with OMB or Congressional systems.

It takes approximately two years to develop the DoD's budget with the PPBS system, and then another year for Congressional approval. The first year consists chiefly of long-range planning by the Joint Chiefs of Staff (JCS). The JCS addresses threats posed to the United States through the next twenty years. It formulates the directions and emphasizes that the services should follow to meet these threats. Early in the year (January-February), the JCS publishes the Joint Strategic Planning Document and Supporting Analyses, Book I (JSPDSA I), which consists of threat appraisal, military objectives and strategy, and force planning guidance to the services. After feedback is received from the services and analyzed, the JSPDSA II is published near the end of the year; it assesses the "reasonable assurance" of successfully executing the national military strategy. An executive summary of the JSPDSA I and II, called the JSPD, is forwarded to the SECDEF in November.

Based on the JSPD and other inputs from the President, the National Security Council, and the OSD staff, the SECDEF publishes its initial version of the Draft Consolidated Guidance (CG) to the services in the January/February time frame. The initial Draft CG marks DoD's transfer from conceptual planning to programmatic planning. After review by the services and the JCS, the final Draft CG is published in March. (The CG is always in a "draft" status.)

The CG tells the services the types of programs and force structure they should develop over the next several years to support the national military strategy. The guidance is both fiscal and programmatic. It sets limits on

the dollar sums of the services' budgets, and it directs that certain programs or forces should be provided. This guidance is in a multi-level, multi-year format. It specifies three different program sizes (minimum, basic, and enhanced) for each service in terms of total dollar expenditures in each of five years. It directs that certain programs should be programmed in the minimum, basic, or enhanced levels.

The planning effort that concludes with the Draft CG is followed by a year of programming and budgeting. First, the services use the Draft CG of March to revise their overall programs. In May, they each submit a POM to the SECDEF that shows what they propose to program with the three different funding levels of the CG. The SECDEF then develops an overall defense program from the POMs (and from the program submissions of the defense agencies, e.g., the Defense Communications Agency). The three-level POMs provide the SECDEF with the flexibility (1) to adjust the defense budget from approximately 5% below current expenditures to 5% above, to reflect the emphasis that OMB and the President choose to pursue; and (2) to redirect the emphasis of defense among the services to carry out the national military strategy. The services' development of the POMs is discussed at more length in Section 2.3.1.

At the OSD level, the development of the defense program from the POMs proceeds as follows: first, the JCS staff studies the POMs to see how well they satisfy the JSPD and CG; their review is forwarded to OSD. Second, the OSD staff reviews the POMs to judge their congruence to the CG. The result of both reviews is a set of issue papers (IPs) prepared by OSD that challenges various features of the POMs. The services and the JCS respond to these IPs. Then the SECDEF publishes the Program Decision Memorandum (PDM), the SECDEF's proposed defense program. After evaluating

specific objections to the PDM from the services, the SECDEF publishes the Amended PDM (APDM) in September, and this marks the end of the programming phase.

The services next present budgets to OSD for implementing their approved programs in the APDM. These are reviewed and revised by OSD and OMB and become, collectively, the SECDEF's budget proposal to OMB and the President. The President presents his budget to the Congress in January, two years after the publishing of the JSPDSA I, and one year after the publishing of the Draft CG. The Congress has nine months after the President has presented his budget to review it and enact the federal budget for the fiscal year beginning October 1. In recent years, the Congress has taken twelve months to accomplish this, rather than nine. Thus, the period from JSPDSA I to federal budget is three years.

This discussion of DoD PPBS has focused on certain milestones that occur during preparation of the DoD budget: JSPDSA I, Draft CG, the POMs, and the APDM. The PPBS is roughly analogous to a relay race: on a race track, the milestones mark the passing of the baton from one runner to another. However, the PPBS relay has some unusual features. First, the runners not only pass the baton to the next runner, they also receive another baton and keep running. Though they get some rest, the planners never stop planning, the programmers never stop programming, and the budgeteers never stop budgeting. They work in one-year cycles, and once a year they pass off their year's work to other workers and pick up their next year's work from yet other workers. Second, unlike relay runners, the PPBS runners start running to catch the next baton well before it is ready to be passed. The programmers have done four months' work before the Draft CG is issued so that they will be prepared to follow it. The budgeteers use the PDM to start work so that they can respond quickly to the APDM. The system simply would not

function if the programmers and budgeteers did not have themselves fully in motion as the Draft CG and APDM were passed to them.

A cornerstone of DoD PPBS that provides coordination, continuity, and visibility to the defense program is the SECDEF's Five-year Defense Program (FYDP). It exists as a data base containing (1) historical data on the defense program as executed since 1962; (2) the current program as authorized and appropriated by Congress; and (3) the multi-year program for the future that evolves during the PPBS. The FYDP's multi-year program is updated three times every year to reflect (1) the POMs submitted by the services (May); (2) the budgets submitted to OMB by the services and OSD (October); and (3) the President's budget (January).

2.2.3 Navy/MC PPBS - Because the Marine Corps is a part of the Department of the Navy, its program is developed as part of the DoN POM rather than as an independent MC POM. However, a division of the DoN's PPBS between the MC and Navy staffs has been established by the Secretary of the Navy (SECNAV). In this division, the MC's PPBS for MC personnel and ground-warfare capabilities is virtually autonomous from the Navy staff's PPBS, while the MC PPBS effort for air warfare and other program areas occurs jointly with the Navy staff. This division is subject to change; for instance, military construction to support the MC has recently come within the autonomous MC PPBS. For the autonomous efforts, MC staff operates under separate fiscal and programmatic guidance from the SECNAV. Under this guidance, it develops the so called "green-dollar POM" which the SECNAV then incorporates into the DoN POM.

Fiscal guidance for the MC-developed (green dollar) portion of the DoN POM is determined by the SECNAV. As a rule, this fiscal guidance for the MC is obtained by

multiplying the CG's guidance to the DoN by a fraction. The fraction is a ratio of current MC expenditures to total DoN expenditures. The fraction is a very important determinant of the MC's program, and hence it is defined by the SECNAV in consultation with the Commandant of the Marine Corps (CMC) and the Chief of Naval Operations (CNO). It determines the so called "blue-green split" that divides the CG's multi-level, multi-year dollar totals for the DON between the CNO and CMC's programmers. Given this split, the HQMC builds its independent portion of the DoN POM.

However, as already mentioned, a substantial portion of the DoN POM that is related to the MC is not programmed by the CMC because it is tied closely to the CNO's program. This is true of MC aviation procurement, for instance, and in this case, the CMC proposes an aviation program to the Navy staff. The Navy staff develops the related CNO's POM submission. The same procedure is followed for the Marines' research, development, test, and evaluation (RDT&E) activities, which are part of the CNO's POM submission.

2.2.4 MC PPBS - As discussed above, the SECNAV assigns part of the DoN PPBS to the CMC. Generally, the CMC provides all planning, programming, and budgeting related to MC manpower, base operations, fleet support, military construction, and ground-warfare readiness and modernization. The CMC delegates planning to the DC/S for Plans, Policies, and Operation (PPO); programming to the DC/S for Requirements and Programs (R&P); and budgeting to the Fiscal Director of the Marine Corps (FD).

HQMC's PPBS is identical in its broad features to the PPBSs of the Army, Air Force, and Navy. In the planning phase, DC/S PPO's staff makes use of JCS and OSD

intelligence assessments to revise long- and short-range MC plans and policies; and it interacts with OSD in shaping the CG. In the programming phase, DC/S R&P's staff reviews and revises the MC's force structure; it reviews current operations and acquisitions, requests program initiatives from the MC staff, prioritizes these with the current-capability items, and packages the result into the green-dollar POM; it responds to issue papers in shaping the APDM. In the budgeting phase, the FD staff divides the POM into budget bands, puts it in budget format, and takes it through reviews by the Comptroller of the Navy, OSD, and OMB.

The programming phase of the MC's green-dollar PPBS and, more narrowly, the MC's strategy and methodology for programming, are described in detail in later sections. Several broad features of the programming effort are as follows:

- (1) Staff committees - During the preparation of the green-dollar POM, two ad hoc committees assist DC/S R&P. These are the POM Working Group (PWG), composed of action officers representing the MC sponsors (i.e., the major staff offices); and the POM Coordinating Group (PCG), composed of General Officers representing the sponsors. The green-dollar POM is reviewed and revised by the PWG, the PCG, and the Chief of Staff's Committee before reaching the Commandant.
- (2) Mission-area format - For several years, the Congress, OMB, and DoD have sought to emphasize military "missions" in establishing the defense budget. Both the Congressional Budget Act of 1974 and OMB Circular A-109 require the DoD to display budget resources in terms of mission areas. Consistent with this emphasis, the MC staff uses mission areas

as the structure for organizing all aspects of its green-dollar programming effort. This mission-area emphasis in programming proceeds through four stages:

- (a) the definition of mission areas;
- (b) the determination of MC capabilities and deficiencies within the areas relative to the current and future war threats;
- (c) the solicitation and prioritization of program initiatives to decrease the deficiencies; and
- (d) the packaging of initiatives into sets that solve the mission deficiencies in a balanced fashion.

The missions for POM 83 are shown in Figure 2-1. The horizontal lines in the figure signify clusters of mission areas that fall naturally to one or another of the MC sponsors. The sponsors provide the military expertise for prioritizing program initiatives within and across the mission areas in the clusters; the DC/S R&P provides the expertise for balancing the priorities of initiatives across the clusters.

(3) Decision-analytic orientation - The CMC uses the PPBS as a primary management system. The programming phase is the CMC's forum for:

- (a) determining goals and shortfalls related to USMC missions;

AMMUNITIONS CLOSE COMBAT FIRE SUPPORT MINE WARFARE LAND COMBAT SUPPORT AMPHIBIOUS WARFARE PREPOSITIONING ICELAND PREPOSITIONING NORWAY MARITIME PREPOSITIONING	MANPOWER AND PERSONNEL MANAGEMENT
	SELECTED MARINE CORPS RESERVE UNITS RESERVE PRETRAINED INDIVIDUAL MANPOWER
TRAINING AND EDUCATION	TRAINING AND EDUCATION (O&MMC) FLEET MARINE FORCE SUPPORT (O&MMC) BASE COMMUNICATIONS (O&MMC) ADP (O&MMC) RECRUITMENT AND ADVERTISING (O&MMC) BASE OPERATING SUPPORT (O&MMC) REAL PROPERTY MAINTENANCE ACTIVITIES (O&MMC) SUPPLY AND MAINTENANCE (O&MMC) ADMIN (FIELD-O&MMC) DEPARTMENT ADMIN (O&MMC) NON-DEPARTMENT ADMIN (O&MMC) OTHER HQMC ADMIN (O&MMC)
GROUND AIR DEFENSE TACTICAL C ² (AIR) OFFENSIVE AIR SUPPORT OTHER AVIATION SUPPORT	
LAND COMBAT SERVICE SUPPORT MILITARY CONSTRUCTION OPERATIONAL SUPPORT	
TACTICAL C ² (GROUND) ADP/DATA COMMUNICATIONS TACTICAL COMMUNICATIONS	
TACTICAL SURVEILLANCE, RECONNAISSANCE, AND TARGET ACQUISITION ELECTRONIC WARFARE AND COUNTER C ³ I TECHNICAL SURVEILLANCE COUNTERMEASURES	

Key:

- ADMIN = Administration
- ADP = Automatic Data Processing
- C² = Command and Control
- C³I = Command, Control, Communications, and Intelligence
- O&MMC = Operations and Maintenance, Marine Corps

Figure 2-1
MARINE CORPS MISSION AREAS AND MISSION CLUSTERS

- (b) discovering options for new action;
- (c) analyzing the options to discover their strengths and weaknesses relative to one another and to current actions; and
- (d) selecting a program of new and current actions.

As such, the development of the POM is the CMC's primary management process for defining, analyzing, and selecting the multitude of program decisions needed to develop the USMC's capabilities in a balanced, integrated manner. That is its function and its orientation.

2.3 Conceptual Framework for the Application of Decision Analysis to the MC's POM Development

The purpose of this section is to define the Marines' programming problem from a methodologist's perspective, i.e., to cast it in terms that suggest the decision-analytic methods that can be applied to it most effectively. The section begins with some basic features of the MC programming problem. The MC's general approach to programming is characterized as a method that aims to simultaneously (1) promote a larger budget to fulfill unmet military requirements, and (2) rationally allocate its budget to produce as strong a military capability as possible within resource constraints. The steps in this approach are outlined. Among them, the step of developing an MC staff consensus on the relative importance of all projects competing for programming is identified as the key step for decision-analytic support.

2.3.1 Description of the programming problem - The general programming problem, of which the Marines' is

typical, is a dual problem. It is to plan how to (1) obtain resources and (2) optimally allocate these resources to activities and acquisitions if they are obtained. These twin features of the problem are inextricable since the annual program submission is simultaneously a proposal to obtain resources and a commitment on how to allocate whatever resources are obtained. Inevitably, the proposal to obtain more resources is judged in light of the overall plan for spending.

The problem has many features common to standard resource allocations in which a known but limited resource (e.g. man hours, investment dollars, operating dollars, or facility space) must be optimally apportioned to a set of projects or programs competing for it, realizing that

- o each project can be given various levels of resource corresponding to different levels of operation or investment;
- o because of limited resources, not every project can be given the total resources it could reasonably use; and
- o the projects have varying degrees of importance based on fulfilling different broad institutional goals.

For such problems, the general solution is to develop relative measures of cost and benefit for each level of each project. From these one determines the most cost-effective allocation of resources to the projects, i.e., an allocation that gives the most benefit for the amount of resources expended. Such analyses take many forms and are applied to many kinds of problems, ranging from the design of new products to the design of multi-party negotiations.

The identification of projects and the determination of their costs and benefits are key aspects of POM development. However, because the MC staff is not merely allocating resources it already has, but requesting resources, straightforward cost-benefit analysis must be tempered with other considerations in arriving at the program to propose. First and most importantly, external competitors for resources can win an MC project's proposed resources if one of their projects gives more value for the resources expended. Therefore, the MC's projects must look as valuable as possible to improve the likelihood that they will be accepted into the FYDP and the DoD's budget. Unfortunately, a cost-effective POM submission can appear weaker than it really is: compared to less cost-effective submissions, it will usually have more lower-cost projects of lesser importance, though in aggregate they are more valuable. Speculatively, a large number of small projects is more difficult for the DoD to evaluate and understand than a small number of larger, more important projects.

A second feature complicating a straightforward resource allocation approach to programming is the multi-level nature of the program. The MC's POM submission must show the CMC's program for three increasing levels of overall funding specified by the SECNAV. These are the minimum, basic, and enhanced levels, respectively. On its own initiative, the MC may also propose to spend an "over guidance" amount beyond the enhanced level. This defines an "over-guidance level" for the submission. Projects that are not programmed in one of these four levels are said to be in the "unfunded level."

Several features of the multi-level format impact methodology:

- (1) The minimum-level program is protected from resource competition. As a rule, the MC and the other services are guaranteed their minimum-level programs. This means that the minimum level can be used to protect programs. It creates an incentive for the services to put some weaker programs under protection and risk some stronger programs in the basic or enhanced levels as tools for obtaining more funding.
- (2) The basic-level program must be presented as a set of projects that merely builds upon the minimum-level program; and the enhanced-level program is a set of projects that build upon the basic-level program. Contrary to this format, a resource allocation based on cost-benefit analysis could exclude projects at the basic level which it included at the minimum level.
- (3) The basic and enhanced programs must be "packaged" into decision units (consolidated decision package sets) for the SECNAV. These packages (normally not more than thirty for the MC), rather than individual projects, will compete for resources. To make up packages that are understandable as unified wholes, similar projects will tend to be packaged together even though they vary widely in importance and cost effectiveness and would not be put together in a straightforward resource allocation.

2.3.2 Approach to the programming problem - Given the foregoing features of MC programming, the MC staff's approach to the problem is a judicious mixture of broad strategy, systematic procedures, scientific techniques, and ad hoc

problem solving. This section outlines these elements of their approach.

2.3.2.1 Goals for programming - As to broad strategy, the CMC's first programming priority is to assure that the minimum-level program defines a functional, balanced Marine Corps, even though this means (by definition) operating with five percent less than current funding. This is the CMC's first priority because experience has shown that the Marines cannot count on obtaining the basic-level program, though they almost always obtain the minimum-level program. This first priority leads to great care in preparing the minimum-level program. Its preparation is based upon a systematic review and adjustment of Marine Corps missions, manpower (military and civilian), and current acquisitions. New acquisitions may be incorporated into the minimum level to the extent they are more important than current acquisitions or operations, but they seldom are more important.

Broadly speaking, the CMC's second programming priority is to construct a basic-level program that maintains or improves near-term readiness through the replacement or overhaul of obsolete or unserviceable equipment, the maintenance of equipment, and the maintenance of facilities. More important issues of readiness, such as recruitment and training, are included in the minimum-level program. Some new capabilities may be programmed at the basic level, but not many.

The CMC's third programming priority is to construct an enhanced-level program that will improve the MC's readiness in the future through the application of current engineering technology to established MC requirements. These applications would add or extend current MC capabilities significantly.

2.3.2.2 Phases of programming - The POM submission results from a set of parallel program developments initiated and coordinated by DC/S R&P. The schedule in Figure 2-2 (a and b) shows the parallel milestones of the POM 83 cycle that control the development of a military manpower program, a civilian manpower program, a procurement program, an operations and maintenance (O&M) program, the POM submission, and a mission area analysis. The parallel program developments can be viewed from several perspectives.

First, they divide the development of the POM submission into two ordered phases: (1) the military and civilian manpower programs and the "constrained minimum-level" O&M program are finalized first; then (2) the procurement and "unconstrained" O&M program are finalized afterwards. The first phase establishes a "constrained minimum-level" core program that requires less resource than the minimum level; the second phase builds from the core up through minimum, basic, enhanced, and over-guidance levels. Given the strategy described above, the first phase is considered more critical than the second.

Second, in both these phases the procedures order staff action through the same sequence of stages: (1) a request for program initiatives; (2) a prioritization of initiatives; and (3) the construction of a program from the prioritized list. These stages set the inner rhythm of POM development. They vary markedly in MC participation: (1) the request for initiatives is MC-wide; (2) the prioritization is only Headquarters MC-wide; and (3) the construction of the program is effectively limited even further to the POM Working Group and the POM Coordination Group. They vary markedly in effect: (1) the request produces a large volume of initiatives; (2) the prioritization screens, validates, and ranks the initiatives in terms

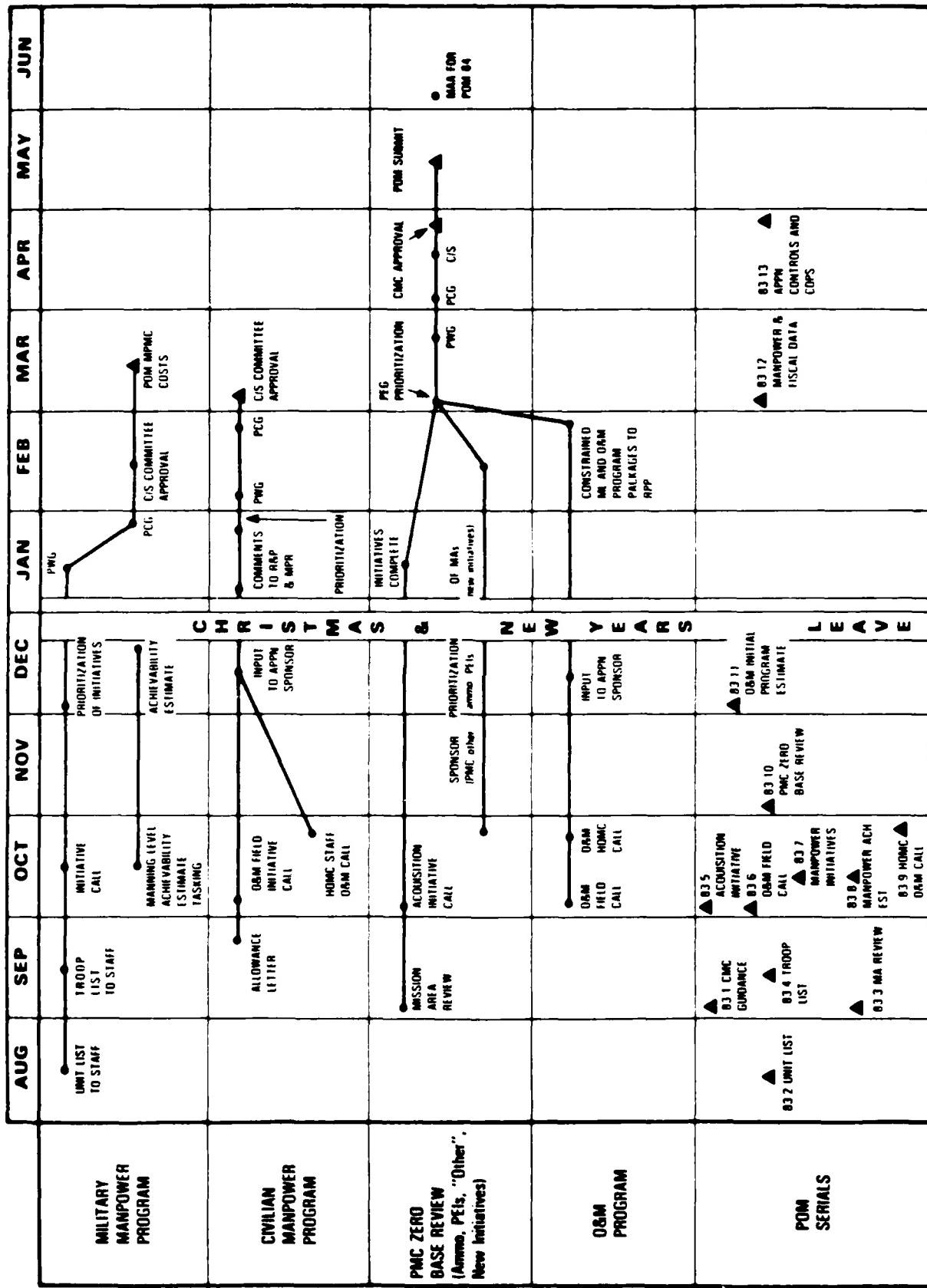


Figure 2-2a
POM 83 SCHEDULE

PWG	POM Working Group
PCG	POM Coordinating Group
C/S	Chief of Staff
MPMC	Military Personnel, Marine Corps
O&M	Operations and Maintenance
APPN	Appropriation
AMMO	Ammunition
PEI	Principal End Item
MA	Mission Area
PEG	Program Evaluation Group
CMC	Commandant of the Marine Corps
MAA	Mission Area Analysis
HQMC	Headquarters Marine Corps
ML	Minimum Level
RPP	Program Coordination Branch, Deputy Chief of Staff for Requirements and Programs
ACH EST	Achievability Estimate
CDPS	Consolidated Decision Package Set

Figure 2-2b
KEY TO FIGURE 2-2a

of military worth; and (3) the construction phase pares, re-orders, and repackages the initiatives into a marketable, cost-effective program that meets DoD/DoN fiscal and programmatic guidance. They vary markedly in character: (1) the request is a relatively open, nonjudgmental solicitation of programs; (2) the prioritization is an intensely evaluative, judgmental process that examines the merits of programs individually; and (3) the construction stage is marked by aspects of pragmatic programming where programs become mere elements of packages and must be trimmed and combined in ways that make the packages most attractive.

2.3.2.3 Scientific techniques - The prioritization stage of POM development involves several procedures that draw directly on psychological and economic science. These procedures introduce an objective logic of analysis and evaluation to the prioritization to enhance its quality, its efficiency, and its acceptability to the MC staff. It is a logic that prescribes how--in general terms and in specific cases--to assess professional military judgment about program worth, to organize and integrate the collection of these judgments efficiently, and to use the results to set program priorities. Section 3.0 describes this logic, while Section 4.0 describes the procedures used to carry it out.

2.3.2.4 i hoc problem solving - Some parts of the prioritization stage are not amenable to general predetermined procedures but require ad hoc problem solving. The reconciliation of professional military judgments, for instance, always requires an approach specific to the problem and personalities at hand. Similarly, the packaging of programs during the construction stage, though based largely on the prioritization stage, must be adapted to the specific programming "environment" the Marines find themselves in each year, i.e., to the particular programs and priorities that the OSD, OJCS, and the other services are advocating.

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3.0 DECISION-ANALYTIC STRATEGY AND GUIDELINES

Within the Marines' approach to programming, prioritization is the key feature that affects all others: (1) the process, methods, and guidelines established for prioritization naturally create incentives that determine the character of the sponsors' initiatives; and (2) the prioritized list of programs forms the basic guide for constructing the POM submission. Decision-analytic methods are used primarily by the MC staff to support the prioritization stage of programming, including:

- (1) the design of prioritization procedures;
- (2) the proper formulation of program initiatives;
- (3) the collection of professional military judgments about the importance of initiatives;
- (4) the integration of these judgments; and
- (5) the prioritization of programs using judgments of worth tempered by considerations of program costs.

This section presents the Marines' methodological strategy and guidelines for conducting the prioritization stage of programming. As described already, this stage is applied several times during POM development--first to military manpower initiatives, then to civilian manpower initiatives, then to the procurement and O&M initiatives. It may also be applied selectively to the MC's RDT&E initiatives and its "blue-dollar" aviation initiatives. The features of prioritization methodology described in this section apply equally to all these different tasks.

The section begins with some background on the various approaches to program prioritization. It then describes the MC's approach and discusses the unique features that distinguish it from the other services. Finally, it describes the MC's present guidelines for carrying out the approach. Section 4.0 presents the detailed methods used to implement these guidelines.

3.1 Background on Prioritization in DoD

A POM is a proposal to spend money on specific programs and forces. Through the minimum, basic and enhanced levels, it identifies the relative importance of programs to guide DoD decision makers as they allocate scarce resources across the military services. Obviously, the same set of programs can be packaged and prioritized several ways by a service. The prioritization problem is to build the best POM possible within normal constraints of time and effort.

All the services approach the POM as follows: (1) develop a prioritized list of programs that shows the service's order of preference among them individually or in large groups (i.e., minimum, basic, enhanced); (2) package the large list of programs into a DoD-required, smaller number of packages, using the priority list as a guide. In all the services, the first step is performed through systematic staff action. The second is always a matter of ad hoc programming judgment since there is not a generally accepted logic for consolidating programs into packages. (This is not to say such logic cannot be developed, just that each service uses a unique logic.) The overall logic of POM development is a belief that if a good priority list can be developed, then the packaging of programs into a POM can be accomplished well by experienced programmers.

All the services approach the prioritization of programs through hierarchical decomposition: a prioritized list is formed by (1) assembling several independent lists for functionally different areas, and (2) merging the independent lists. This hierarchy may extend to several levels as lists are made from lists made from lists. There are two approaches to this hierarchical prioritization. The first is exemplified by OSD, the SECNAV, and the CNO; the second, by the Army, Air Force, and Marine Corps.

In the first approach, called "multi-level programming," the independent lists are designed by independent functional sponsors to meet centrally determined, multi-level fiscal and programmatic guidance. Thus, OSD's CG specifies fiscal constraints to the services for minimum-, basic-, and enhanced-program "levels." The constraints are in dollars of total obligational authority for each of the five POM years. Along with the fiscal guidance, the CG specifies programmatic goals that the services should meet at each level. Having received the fiscal and programmatic guidance, the services determine their own programs for minimum, basic and enhanced levels. While their placement of programs in the levels is subject to review, it is basically their responsibility to design their own programs from the guidance.

The minimum, basic, and enhanced levels of the CNO's POM submission are formed by combining minimum-level programs submitted by the CNO's resource sponsors, then their basic-level programs, and then their enhanced-level programs. Since each sponsor's submission meets CNO fiscal guidance for each level, the CNO's input to the DoN POM meets SECNAV fiscal guidance. This is the simple picture, of course. In practice, the CNO's programmers move some of each sponsor's programs from one level to another. In this regard, we may note that the OSD/SECNAV/CNO method of prioritization has no formal provision to move programs from one level to another

based on service or sponsor priorities. The services or sponsors are not required to prioritize programs within each level, though they often do put them in approximate order. Thus, it is not possible to determine from a service's submission exactly what its priorities are among programs and program packages.

The OSD and Navy methods extend considerable programming authority to the independent program sponsors in that each sponsor selects the program level for each of its programs. If each has followed its guidance, then OSD and the Navy can produce a total program without further analysis merely by adding the sponsors' programs for each level. The true picture is much more complex, but this simple one is adequate to contrast the OSD/Navy method with the Army/Air Force/Marine Corps method.

Hierarchical prioritization is handled differently from the OSD and the Navy by the Army, the Air Force, and the Marine Corps. For these services, when independent sponsors are requested to propose program initiatives, they are not given fiscal guidance or programmatic guidance tied to funding level. That is, their proposals are not fiscally and programmatically constrained. Rather, the sponsors are encouraged through guidance to propose initiatives that effectively satisfy needs. This means practically that (1) the programming headquarters receives a larger number of initiatives than it can program even at the enhanced level; (2) the programmers rather than the sponsors assign initiatives to funding levels; and (3) the programmers rather than the sponsors implement the OSD programmatic guidance relative to funding level.

Once the Army, Air Force, and MC receive program initiatives from sponsors, they proceed by different methods to prioritize them. The Army for instance, will assign each to

a mission area proponent (MAP), and the MAPs will screen, evaluate, and prioritize them. Then the separate prioritized lists from the MAPs will be merged by a central programming office. The Marines, on the other hand, assist the sponsors to prioritize their own initiatives. The prioritized lists are merged by a central MC staff. In each case, a complete order (in the mathematical sense) is determined separately for each sponsor or proponent's initiatives. Then a complete order is determined for all initiatives by "merging" the sponsors' or proponents' lists. By "merging," we mean that each sponsor or proponent's initiatives in the final list are in the same order they were in the separate lists, with occasional exceptions. To coin a term, we shall call this method of prioritization "priority programming" to distinguish it from multi-level programming. It differs from the latter by building a complete priority order of programs rather than merely assigning each program to one of three fiscally constrained levels.

The simplest method for merging several prioritized lists requires superhuman mental skills in military applications. This method is called the "blue card" method (BCM) because we first saw it carried out with blue 3x5 file cards. Several stacks of cards were made, one for each sponsor, and each card had the name of a program initiative.

Each sponsor put his cards in order of program priority with his best program on top. The stacks of prioritized cards were put on a table, and several colonels with no responsibility to any program sponsor picked one card at a time from the stacks to form one single stack. The new stack had all the cards in it, and they were in the priority order that the group had determined. It had several hundred cards and represented several billion dollars.

While the BCM sounds plausible, it turns out to have serious drawbacks. The basic problem is that each of the several hundred programs to be prioritized must be examined at least once by the group, and each program must be compared to very different programs from other sponsors. It is impossible for a reasonably sized group (5-20 people) to have both an in-depth knowledge of each of several hundred programs as well as the broad, unbiased service viewpoint needed to merge all the programs during the time-constrained POM development. To our knowledge, no one who has tried this process has continued to use it.

These observations about the BCM would not apply if there were only a few initiatives and only a very few broad objectives to be met with the initiatives. The BCM might work well for a small organization with a small budget. We believe it will seldom work well for a large organization such as the MC. Although it will correctly identify the best and the worst programs, lack of information or lack of a sense of priorities will tend to randomize the priorities of the intermediate programs that are the subject of difficult decision making. The MC's method overcomes these difficulties, as explained below.

3.2 The MC's Method of Prioritization

The MC's approach to priority programming is an innovation that puts it ahead of the other services in its ability to bring the collective expertise of its staff to bear on program development. This section discusses the essential elements of their method. These are (1) disciplined formulation of initiatives; (2) hierarchical, quantitative evaluation of initiatives; and (3) cost-effectiveness analysis. Subsequent sections describe the prioritization ground rules and the detailed procedures for carrying out the method.

3.2.1 Formulation of initiatives - A deliberate approach to the formulation of projects is a key element of priority programming systems. The process of prioritization is frustrated if the items being evaluated do not fit the process; their priorities become obscured. For instance, if items are formulated strictly within appropriation lines (because they can be managed more easily by appropriation sponsors, if executed), they tend to be impossible to evaluate singly in a prioritization system that is focused on mission capabilities. This is because a single, executable mission capability almost always involves several appropriations (to cover investment, transportation, training, operations, maintenance, and manpower), and no one of these should be evaluated singly, any more than "left shoe" should be evaluated against "right shoe" to fulfill the mission "walking."

At the MC headquarters, criteria for formulating initiatives are first communicated to the sponsors, and then they are used to validate the sponsors' initiatives before they can compete for a place in the POM. No institution should expect success in applying the MC's method (or any other), if it is unable to discipline project formulation similarly. Without such control the system invariably breaks down.

The staff's MC criteria for formulating initiatives are that they should be (1) executable; (2) incremental; (3) mission-oriented; (4) independent; and (5) significant. These criteria overlap to some degree, but they provide five different ways of validating initiatives as POM competitors.

An executable initiative contains within it all the parts necessary to its implementation, and each part is capable of implementation. An initiative to "buy trucks" is not executable if there are no trucks to buy. An initiative

to "equip a division with M198 howitzers" is not executable if it does not include prime movers for the howitzers, since the howitzers are useless if they cannot be moved.

An initiative is incremental if (1) it has relatively small though significant importance when compared to the MC's total capability, and (2) it is designed as a change to the status quo in which something new is added and something current may be deleted. As to the first point, although the POM includes large changes when they occur (e.g., the rapid deployment force in POM 82), it is several hundred smaller changes that are the real subject of POM prioritization from year to year. The larger issues are decided separately and do not compete in the prioritization. However, it is not always clear to everyone whether an issue is so large that it should be decided separately. An example of an issue in this gray area between large and small in the MC's POM 82 was the replacement of unserviceable, obsolete computers vital to the MC's tactical and general logistics and administrative systems. Many among the MC staff were completely unaware of the degree to which all aspects of MC operations depend on these computers. The Marines leave such an issue in the prioritization process with the understanding that its status as a competitor may be changed later.

The concept of an "incremental" initiative concerns more than size, however. Primarily, the word "incremental" puts emphasis upon the full difference in MC operations between having and not having an initiative. A validly incremental initiative contains within it not only something new but also the proper adjustments to current and future operations that should accompany it. An initiative to buy a new type of truck for instance, should include explicit plans to decrease purchases and maintenance of the current type of truck. Otherwise, it is not incremental, and it is not formulated properly.

For the MC, a properly formulated initiative must be "mission-oriented" as well as executable and incremental. The MC first used mission areas as the basis for POM development for POM 81. Seventeen mission areas were defined. This concept was successful, and it was used again for POM 82, which had 26 mission areas. The 39 mission areas planned for POM 83 were shown above in Figure 2-1.

A mission-oriented initiative is defined and evaluated in terms of one specific mission capability that it will provide the Marine Corps (though it is usually named for the chief item it provides). Given its mission orientation, the MC's evaluation of initiatives is outcome-oriented rather than input-, process-, or institution-oriented. That is, it lets the Marines build a program based on improving explicit military capabilities rather than merely improving its base of resources or its management of personnel and resources. Contrary to the mission-area orientation, a tendency of program designers is to define programs along appropriation lines. In this case (1) no initiative provides a complete mission capability, only parts; and (2) an initiative may combine parts of several different mission capabilities because they can be grouped logically in the same appropriation (or budget) line. Both these situations cause confusion in a mission-oriented analysis.

The next criterion is that initiatives should be independent. This means that ideally,

- o the military capability provided by any one initiative should not depend strongly on the capabilities that would be provided by other initiatives if they were funded; and
- o the resource requirements of an initiative should not depend strongly on the funding of any other initiative.

It requires considerable effort to formulate independent programs. However, the fact that the programs are all increments to the core of MC activities that is not being prioritized (Section 2.3.2.2) makes independence easier to achieve than one might expect. The tendency to be guarded against is to formulate initiatives so narrowly that they provide only part of a mission-oriented capability, in which case their usefulness strongly depends on the funding of the other parts.

Apart from such tendencies, there is always difficulty in formulating logical independent initiatives for the missions of communications, command and control, automatic data processing systems, and base operations. These missions require networks of equipment, personnel, or operations. Often an executable mission-oriented initiative can only be formulated as a combination of several integrated changes to the network. Rarely will such initiatives be independent since they represent different ways of integrating the elements of the same network. A systematic strategy for formulating such initiatives is outlined in Section 4.3.3. It makes possible their prioritization along with the rest of the POM competitors.

Finally, a POM initiative should be significant to compete. The MC staff uses the rule of thumb that current capability programs should expend resources of at least \$1M in five years to compete with new initiatives. This assures that the current capability will have adequate scope to merit careful evaluation along with all other items. This criterion is not held rigidly, but it is the assumed rule and is enforced with few exceptions. No rule of thumb is applied to new initiatives themselves, but small initiatives are generally included in the POM as "fillers" rather than as true competitors for resources.

In summary, the MC staff requires each initiative to be executable, incremental, mission-oriented, independent, and significant. When the initiatives meet these requirements, they can be prioritized readily in the MC's priority-programming system. When they do not substantially meet the requirements, they only confound the programming system. The MC staff applies these requirements, therefore, to validate initiatives before they compete for a place in the POM.

3.2.2 Hierarchical evaluation of initiatives - A difficult feature of priority programming for large organizations is the great diversity among their initiatives. For instance, the MC's POM 83 submission will likely contain such dissimilar initiatives as the construction of gymnasiums, product improvement of HAWK missiles, accelerated procurement of howitzer ammunition, replacement of administrative data processing systems, a new computer system to aid the planning of officers' careers, the overhaul of tank-recovery vehicles, and a field water purification unit. To set priorities well among several hundred such initiatives is very difficult at best, if not impossible, because of their dissimilarity.

The MC staff's mission-oriented programming achieves many purposes, and one of the most important is that it groups similar initiatives together under each mission. This grouping makes it practical for officers who are specialists in the mission areas to assist the MC's programmers to quickly and accurately prioritize the initiatives within their specialties without being asked to learn other specialties. Maximum use is made of their special expertise.

The prioritization of similar initiatives within mission areas by specialists solves part of the difficulty of evaluating very diverse initiatives, but only part. The

separate lists of well-prioritized initiatives must yet be merged, for no automatic merge is implicit in the separate lists. (In fact, the MC's separate lists can be merged in literally billions of ways.)

The MC's strategy for merging the separate mission lists is based on the idea of "sampling" initiatives from each list, determining the priorities of the samples, and using these priorities to determine what all other initiatives' priorities should be. To accomplish this, it builds on concepts of mathematical psychology for measuring the importance of projects. The basic process is as follows:

- (1) The within-mission evaluations of initiatives are performed in such a way that analysts can construct an objective numerical representation of the relative subjective importances of the initiatives within each mission, but not across missions. For each mission, bigger numbers signify more important initiatives; and bigger sums of these numbers signify more important packages of initiatives. The numbers are called "mission benefits."
- (2) Three sample initiatives are chosen to represent each mission area. All sample initiatives are briefed by their sponsors to a program evaluation group (PEG). The PEG itself is composed of officers who know the relative importances of the mission areas to the Marines because of their field and staff experience. They generally do not know the details of the sampled programs until they are briefed.
- (3) The PEG evaluates all the sample initiatives as briefed to them. Analysts working with them develop a numerical representation of the importance

of each initiative relative to one another as seen by the PEG. These numbers are called "cross-mission benefits."

- (4) The relative importances of the samples from a mission area may be perceived differently by the PEG and the mission-area experts. If so, the ratios of the initiatives' mission benefits for each sample of three will differ from the ratios of their cross-mission benefits. When the difference is large, the PEG meets with the mission experts to reconcile the differences. In this exchange, the PEG's final perception of the initiatives prevails. If necessary, all of the mission benefits for a mission area are then adjusted mathematically to be consistent with the PEG's final cross-mission benefits for the sample items in the mission area.
- (5) The PEG's final cross-mission benefits are used to determine a single weighting factor for each mission area. The "overall benefit" of each initiative is calculated by multiplying each initiative's adjusted mission benefit by the weighting factor for its mission area. All initiatives are then listed in order of overall benefit, and this list is the final product, subject to "fine tuning."

This process differs strongly from most prioritizations because the Marines' mission and PEG experts not only put items in priority order, but establish a means for comparing any combination of items to any other combination of the items, i.e., for determining which combination would be more valuable. This requires a much more thorough analysis of initiatives than the task of merely putting them in order, but this is necessary if separate lists are to be

merged by taking samples from each. The numerical representation of importance is built from this more thorough analysis. As an important side benefit, the numbers provide an objective means for the mission experts and PEG to communicate about the relative importance they place on initiatives: from a simple ordered list, one cannot learn whether (1) the first item and last item are nearly as important as one another, or (2) the first item is more important than all other items combined. The mission benefits and overall benefits communicate immediately how much importance each item has (1) within its mission, and (2) to the MC as a whole. These improve communications among the MC staff, as well as provide the basis for merging the mission areas.

Practically, the Marines have too many mission areas for the PEG to realistically evaluate samples from all of them at once. Three samples from 38 mission areas would require the PEG to hear 117 briefings and remember them while prioritizing the initiatives--a super-human task. The MC strategy is to merge the mission areas hierarchically: nine clusters containing one to ten missions are separately merged, each with the process described above; then, three samples from each cluster's merged list are taken and used to merge the cluster lists, using the same process. This keeps the human tasks of evaluation within credible bounds. In Figure 2-1, which lists the 38 mission areas the Marines plan to use for POM 83, the bold horizontal lines mark the planned clusters of mission areas.

The psychological motivations for the hierarchical prioritization procedure are (1) to foster more objective and effective communication about subjective matters among professional military experts, and (2) to improve the experts' judgments by reducing in so far as possible, "apples versus oranges" evaluations in the process. By contrast, the blue-card method (Section 3.1) requires a maximum number of apples versus oranges judgments. The MC's procedure deals

successfully with the diversity among their initiatives, leading to prioritizations that have broad support among the MC staff.

3.2.3 Cost-effectiveness analysis - Once the overall benefits are quantified, diverse initiatives are readily compared in terms of both importance and cost. Often, two or three diverse programs of moderate importance are collectively more important but less costly than some other highly important program. Such analyses can be made from the overall benefits and costs of the programs without further professional military judgment. Thus, these situations can readily be analyzed by the programming staff during POM preparation. The question is, what use should be made of such analysis?

As mentioned in Section 2.3, the Marines are not merely allocating resources with their POM, they are also attempting to secure resources. If they program three moderately important initiatives rather than one highly important one, the wisdom of this may not be seen by OSD. If it is not seen, the MC's program will be perceived as weaker rather than stronger. Clearly, great care must be exercised in making cost-effective program substitutions. They might lead to smaller overall funding and a weaker capability if they are not perceived correctly. For this reason, the MC staff makes such substitutions only by exception. On the other hand, cost-effectiveness analysis is performed routinely by the MC staff to look for worthwhile substitutions.

The more mundane roles of cost-effectiveness analysis are:

- (1) to identify important programs that have been "padded" with unimportant but expensive components, which makes them look poorly cost-effective; and

-
- (2) to identify moderately important programs that have failed to include expensive but essential components, which makes them look highly cost-effective.

The Marines' cost-effectiveness analysis is different from the traditional form because "effectiveness" is not measured in objective terms. It is a measure of the subjectively perceived military importance of initiatives. In theory, a POM based wholly on the cost-effectiveness of initiatives would achieve most quickly the MC's collective sense of program priorities, since that is what the "overall benefits" measure. An explicit premise of the MC staff's approach is that the MC ultimately depends for programming on the professional expertise and sense of priorities of its senior managers and staff experts, not on objective measures of effectiveness. Their approach elicits and uses this expertise and sense of priorities to build the POM.

3.2.4 Summary - This section has described the basic elements of the MC's prioritization: (1) disciplined formulation of initiatives; (2) hierarchical, quantitative evaluation of initiatives; and (3) cost-effectiveness analysis. The following section describes the prioritization ground rules in effect for POM 83; these rules may change in the future. Section 4.0 describes detailed procedures for carrying out the method.

3.3 Staff Guidelines

The Marines' method of prioritization requires a coordinated effort by the MC staff. This section describes the assignment of responsibility among the staff for the various judgments necessary to carry out the method. This assignment of responsibility was current for the POM 83 effort.

3.3.1 General -

- (1) Sponsors' initiatives must be formulated properly to compete for funding. Validation procedures include obtaining DC/S-level concurrence from all sponsors that each initiative is executable and incremental. The PWG will establish that they are mission-oriented, independent, and significant.
- (2) Initiatives must be prioritized within mission areas; each initiative is assigned to just one mission area. Upon request from DC/S R&P RPP, sponsors assign representatives to provide military expertise for mission-area prioritizations; then prioritization mergings are conducted by RPP to determine priorities and mission benefits for initiatives. RPP has no role in setting priorities other than to provide methods and procedures. As part of their work, the sponsors' representatives must develop statements of mission-area capabilities and deficiencies.
- (3) When the same sponsor is providing expertise for two or more mission areas, then--if practicable--the sponsor also provides representatives to work with RPP to merge the mission areas. If this is not practicable, the DC/S R&P PEG fills this role.
- (4) The DC/S R&P PEG is selected by RPP. It provides judgments for merging mission lists and mission-cluster lists from sponsors.
- (5) All prioritization activities are coordinated by DC/S R&P (RPP).

3.3.2 Prioritization authority -

- (1) The PWG and PEG have the final authority to set program priorities during the prioritization stage of POM development. This is because the prioritization stage merely sets the start point for the construction stage. It is during the construction that initiatives receive their final place in the program, and then the Chief of Staff's Committee is the final arbiter of initiatives' priorities in the POM subject to the Commandant's approval.
- (2) During the prioritization stage, the PEG determines the relative priorities of the initiatives it samples from the mission areas and mission clusters. That is its sole function. To insure that its judgments are not arbitrary, its work must include a system for full communication and feedback with the sponsors.
- (3) The sponsor-designated experts for a mission area have authority to establish the priorities and mission benefits of initiatives in their mission area, but these are subject to adjustment when the PEG examines sample initiatives from the area. All initiatives, not just the samples, may have their mission benefits adjusted to be consistent with the PEG's evaluation of the samples. Such adjustments are made by RPP; they may be appealed to the PWG.
- (4) Sponsors' expert representatives have authority to determine how the mission areas represented by the sponsor are merged, but the combined priority list is subject to adjustments when sample initiatives are prioritized by the PEG. RPP makes such adjustments.

4.0 APPLICATION PROCESS

This section describes the working-level application of decision analysis to MC POM development. Those MC officers or contractor personnel who apply it are called "decision analysts," and their function is called "decision-analytic support." The section describes in order:

1. the decision analysts' and MC staff's roles, general tasks, and mode of work for decision-analytic support;
2. the MC's technical approach for eliciting, quantifying, and merging officers' judgments of program priorities;
3. the procedures the decision analysts follow when working with mission experts and the PEGs to quantify and combine program priorities; and
4. the MC's technical approach and procedures for cost-benefit analysis.

4.1 Roles for Decision-Analytic Support

The decision analysts, MC sponsors, PEG, and DC/S R&P RPP assume distinct roles in the application of decision analysis. These are illustrated schematically in Figure 4-1.

4.1.1 MC sponsors -

(1) The MC sponsors provide representatives who act as experts on the individual mission areas. In meetings conducted by RPP and the decision analysts, these representatives provide judgments about the priorities of program initiatives.

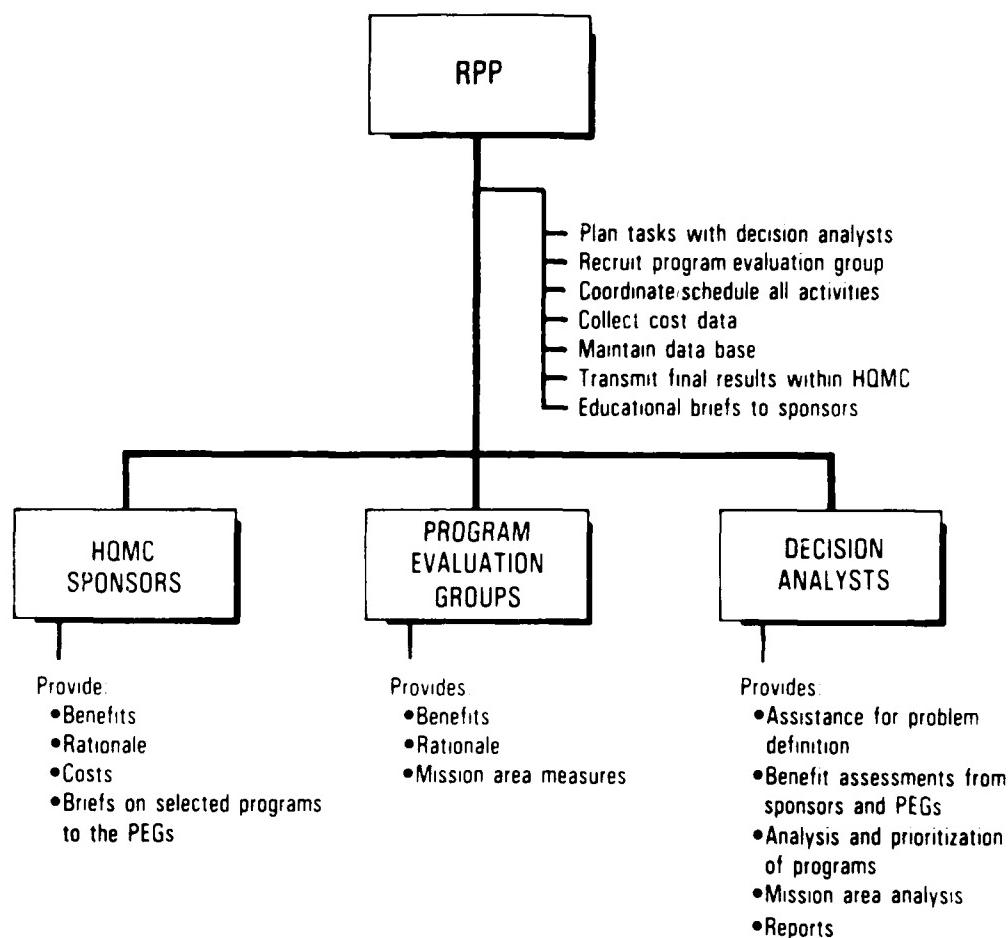


Figure 4-1
OVERALL ORGANIZATION

(2) The sponsors may also provide PEGs to assist the decision analysts and RPP to merge mission areas by cluster.

(3) The sponsors provide briefings to PEGs on the items sampled from their missions or cluster of missions.

4.1.2 PEGs - An official DC/S R&P PEG provides cross-mission expertise for merging the sponsors' prioritized sets of initiatives. This PEG may also be employed to merge a sponsor's mission areas, at the sponsor's request. Alternatively, the sponsor will convene an ad hoc PEG to merge missions. Thus, there may be several PEGs. The functions of all PEGs are: (1) to hear briefings on selected initiatives that represent different missions; (2) to provide judgments of priority among the selected initiatives; (3) to consider objections from the sponsors about these priorities; and (4) to assign final priorities.

4.1.3 RPP - The RPP branch coordinates all decision-analytic support, provides briefings to sponsors and PWG on the support methodology, operates the POM-DBMS, and prepares intermediate and final decision-analytic support reports for the PWG and sponsors. Also, the RPP branch chairs all meetings of the PEGs when they are setting program priorities; in addition, the RPP chairs all meetings of sponsors' representatives when they are setting program priorities within individual missions.

4.1.4 Decision analysts - The decision analysts' role is to carry out the MC's technical approach to prioritization (Section 4.3) and also to continue to improve the approach. The analysts meet with RPP and the sponsors' representatives to quantify program priorities. They meet with RPP and the PEGs to merge mission priorities quantitatively. The analysts design functional improvements to the POM-DBMS when needed by

RPP, and they manage the system's maintenance. They provide methodological consultation to RPP for the continued development of the POM methodology. The analysts provide methodological briefings as needed, as well as summary reports and appraisals of the process.

4.2 General Tasks and Mode of Decision-Analytic Support

4.2.1 Tasks - Prioritization is the major task of decision-analytic support; two secondary tasks are mission-area analysis and software development. The prioritization task (described in Section 4.3) occurs several times as RPP develops the military manpower, civilian manpower, O&M, and procurement programs; it may also occur when the DC/S Aviation develops the blue-dollar aviation program. Figure 2-2 shows the schedule of green-dollar prioritization for POM 83.

Mission-area analysis (MAA) is applied after the green-dollar POM is approved by the Commandant. It is a retrospective, quantitative analysis designed to show the mission-area emphases of the POM submission at the minimum, basic, enhanced, and over-guidance levels. It identifies the deficiencies that remain in each mission at each level. To date, MAA has been used only experimentally by RPP to learn what insights it might provide to improve planning for the subsequent POM. It may or may not be continued in its present form; consequently, it is not described here. A description of the current approach is provided in Waslov and Kuskey (1980), cited in Section 2.4.

Software development for the POM-DBMS must keep pace with changes in the technical approach, working procedures, and data requirements for POM preparation. Part of decision-analytic support is to develop functional specifications for changes to the system and to supervise the consequent software maintenance.

4.2.2 Mode of support - Apart from software development, the great majority of the decision analysts' work consists of person-to-person interactions with the MC staff. Very little independent analysis is done by the analysts. In particular, programmatic recommendations are never made by the analysts. Their recommendations are limited to the methodology, not the content of programming.

The decision analysts work with up to thirty different groups of MC officers. They have one to three meetings with each group; the meetings last one to four hours. Several two-day conferences are led by the analysts to work with the PEGs. Because so many groups participate in POM prioritization, the decision analysts must essentially be on call to RPP to be scheduled at RPP's convenience.

4.3 Methods and Procedures for Prioritization

4.3.1 Introduction - We distinguish four phases of prioritization that require different methods and procedures of decision-analytic support:

1. program packaging;
2. rank ordering and scaling;
3. merging scales; and
4. cost-benefit analysis.

In concept, these phases follow one another. In practice, there is considerable feedback and iteration among all the phases; moreover, there is much parallel progress.

While program packaging is often the critical first step in a successful prioritization, methodology to support it can best be explained within the context of scaling. Hence, it is discussed as a special topic in scaling. Scaling and merging are discussed first in terms of theory and

then again in practical terms. The cost-benefit analysis is discussed separately at the end of the section.

4.3.2 The technical approach to preference assessment -

Let X be the set of all items considered in the MC POM. Let X_i denote the items that are proposed for mission area i ; let x_{ij} be the j^{th} item in subset X_i . (For the Marine Corps, each item appears in only one mission area. Thus, X is partitioned by the subsets X_i .)

The Marine Corps' problem is to develop a priority order for all items, i.e., a complete order for X . They approach this problem by first developing a complete order for each subset X_i and then merging the ordered subsets. To merge the subsets efficiently and effectively, a quantitative representation (scale) of preferences is used. The analyst derives this representation from the Marines' non-numerical answers to questions about items. These questions ask for judgments of the importance of various combinations of items relative to other combinations. The required responses are "less important," "more important," or "equally important." The experts are asked to compare the utility of pairs of programs and relate judgments such as: A is preferred to B; B has more utility than C and D combined; four programs like E are approximately equivalent to F.

The analyst can construct a representation of preferences among items that agrees with the judgments. The analyst develops quantitative scales for each mission area and for sample items across mission areas. The sample items are used to establish weights for the mission area scales that will put them all on the same overall Marine Corps scale.

The method of scaling is based upon a mathematical model of the expert's preferences and assumes a numerical

scale of measurement for the utility of the items in the program set. The scale values represent the relative benefit or utilities of the programs so that "Program A's value is 100" does not mean that A has 100 "utiles" of absolute value. The statement means that it would take 100 programs with a value of 1 to obtain the same utility as Program A, or two programs with a value of 50, etc. The scale is constructed so that multiplication of each scale value by a positive constant preserves the preference order. This capability is a necessary characteristic of the model because of the mission area structure of the MC programs. Each mission area constructs its own scale of relative benefits, and the scales are merged by cross-multipliers. A multiplier is a numerical representation of the utility of the programs in one mission area relative to those in the other mission areas.

The prioritization methodology is a useful tool for situations in which several sets of similar programs are competing for a pool of resources and a priority order across all programs needs to be established. It utilizes the judgments of specialists about the value of programs within their own area of expertise and permits a committee of generalists to merge all the program sets in a simple and efficient manner. The approach divides the task of value assessment, thereby reducing the cognitive strain that can occur when an individual must evaluate and compare many items simultaneously.

Benefit assessment is also useful for evaluating the relative cost-effectiveness of items or sets of items. When given a specific fiscal constraint, one can select the most beneficial set of programs to fund by computing cost-benefit ratios or net benefits (see Section 4.3.4).

The remainder of this section first describes the scaling and merging processes in terms of a mathematical representation model and explains the underlying assumptions

of the model. It then describes the general procedures for assessing and merging preferences. Finally, it presents special techniques for program packaging.

4.3.2.1 Preference representation model and general procedure - To establish a set of rules for assigning numbers to objects in X , we first define relations among the elements of X , such as preference orderings, and a representation of the empirical structure-- X and its relations--by a numerical structure, such as the set of real numbers (R) and its arithmetic relations. We denote the empirical structure of X and its preference relations T_i by $\langle X, T_1, T_2, \dots \rangle$ and the numerical structure of R and its numerical relations S_i by $\langle R, S_1, S_2, \dots \rangle$.

The empirical structure can be represented by a numerical structure if there exists a correspondence ϕ that maps X into R and maps T_i into S_i for all i .

The model which represents the MC priorities and preferences for POM programs is a numerical relational structure. For the elements x and y of X , we define the binary relation, "equal or more important than," denoted by \succeq . Then $x \succeq y$ means x has equal or greater importance than y . We can also define the indifference relation $x \sim y$ to mean that neither x nor y is more important than the other, that is, $x \not\succeq y$ and $y \not\succeq x$.

In addition to stating the preference order of individual programs $x \succeq y \succeq z$, the MC states preferences for combinations of programs such as $(y \text{ and } z \succeq x)$ or $(w \text{ and } y \succeq x \text{ and } z)$. A combination of the elements of X is the simultaneous purchase of two or more programs and is denoted by \circ . The combination operation is represented by the operation of addition in the model; and the binary relation "equal or more important" (\succeq) is represented by

the arithmetic comparison "greater or equal" (\geq). That is, $\langle X, \succeq, \circ \rangle$ is represented by $\langle R, \geq, + \rangle$.

Two topics are to be addressed concerning this representation: the logical properties of the numerical assignment necessary to make it suitable for prioritization, and the procedures for making the numerical assignments.

Properties - We seek assumptions concerning \succeq and \circ that are sufficient to construct a function, ϕ , that: (1) maps all elements of X and all possible combinations of the elements of X into R ; and (2) satisfies:

$$(i) \quad x \succeq y \text{ if and only if } \phi(x) \geq \phi(y)$$

and

$$(ii) \quad \phi(x \circ y) = \phi(x) + \phi(y).$$

We also seek the admissible transformations $\phi \rightarrow \phi'$ that yield homomorphisms into $\langle R, \geq, + \rangle$. If ϕ satisfies these relationships, it will be useful not only for comparing one POM initiative or current capability to another, but also for comparing any set of initiatives to any other set.

The set of axioms sufficient for the representation are given in Krantz, et al. (1971) as well as the proof of sufficiency. For the structure $\langle X, \succeq, \circ \rangle$ with X nonempty, \succeq , a binary relation and \circ , a closed binary operation, they prove that a real-valued function ϕ on X exists which satisfies (i) and (ii) if four axioms hold for all $x, y, z, w \in X$, that is, for all elements in the set X . The four axioms are:

1. \succeq is a connected and transitive relation,
2. $x \circ (y \circ z) \sim (x \circ y) \circ z$,
3. $x \succsim y$ if and only if $(x \circ z \succsim y \circ z)$ and $(z \circ x \succsim z \circ y)$,
4. If $x \succsim y$, then there exists a positive integer n such that $n y$'s are at least as important as x .

The first axiom specifies that the empirical structure $\langle X, \succeq \rangle$ is a weak order: connectedness means that for all $x, y, z \in X$, either $x \succsim y$ or $y \succsim x$. Transitivity means that if $x \succsim y$ and $y \succsim z$, then $x \succsim z$. These conditions are rarely violated once programs are properly packaged. They guarantee that \succeq is an ordinal scale (it preserves the rank order of initiatives) when X is a finite set.

The second axiom requires that the relation \succeq be associative. Since we define combination simply as the decision to purchase all the combined items, the order of combination can be arbitrary.

The third axiom is the monotonicity property and is also called the cancellation law. It requires that the elements of X be independent in value so that the purchase of an item does not cause a change in preference order by increasing or decreasing the value of other items. For the POM program structure, this axiom can be violated in two ways that require special treatment:

- (1) The purchase of items may have a synergistic effect. For example, one might prefer item a over item b , but then prefer the combination of items b and c over items a and c because b and c interact

to produce added benefit; then $a \succeq b$ does not imply $(a \circ c) \succeq (b \circ c)$ and axiom 3 does not hold.

- (2) Items are compensatory so that the purchase of one neutralizes or decreases the value of the other. This effect can occur when similar programs are substituted for one another and the purchase of both is duplicative. For example, a is preferred to b , or $a \succeq b$, but a and c are compensatory so that $(b \circ c) \succeq (a \circ c)$, violating axiom 3.

The Archimedean axiom, axiom 4, requires that any two elements of X must be comparable, i.e., the importance of an item must not be infinitesimally small (or large) relative to any other item. For instance, a set of "must buy" programs that cannot be traded off for other programs cannot be represented by the model.

The tests for validation of these four axioms occur during the construction of the scale which is described in Section 4.3.2.2.

It follows directly from the representation theorem that for any $\alpha > 0$, the function $\phi' = \alpha\phi$ also satisfies the axioms. Thus multiplication of the scale ϕ by a constant produces another scale, ϕ' , which provides an equivalent representation of the structure $\langle X, \succeq, \circ \rangle$.

The multiplicative transformation is useful in the construction of the benefit scale for the POM program set. We first construct individual scales, ϕ_i , $i = 1, 2, \dots, n$ for each of the n mission areas. Then we seek positive multipliers, k_i , for which an overall scale, ϕ , can be defined as $\phi = k_i \phi_i$.

To obtain the k_i , we select a set, X^α , of sample items, one item, x_i^α , from each mission area. If the four axioms hold for the structure $\langle X^\alpha, \leq, \geq \rangle$, we can construct a function ζ that maps X^α into R . The scale ζ describes the empirical relationship of items across all mission areas, and allows us to derive ϕ by:

$$\phi(x_{ij}) = \frac{\zeta(x_i^\alpha)}{\phi_i(x_i^\alpha)} \cdot \phi_i(x_{ij}).$$

$$\text{Thus, } k_i = \frac{\zeta(x_i^\alpha)}{\phi_i(x_i^\alpha)}.$$

The properties of ϕ are that: (1) $\phi(x_i^\alpha) = k_i \phi_i(x_i^\alpha) = \zeta(x_i^\alpha)$ and (2) ϕ is equivalent to ϕ_i for any given mission area. Because of these properties, it is assumed that all initiatives are properly scaled by ϕ to the extent that all the ϕ_i and ζ functions are developed well, though most of the initiatives have never been directly compared across mission areas.

The procedures for the construction of the scales, ϕ_i , ζ , and ϕ , and the assignment of numerical values to items are described below. A more detailed description is given in Section 4.3.2.2 with an illustration of benefit assessment tactics.

General Procedures - The procedure for defining ϕ , the overall benefit scale, begins with the construction of individual mission-area scales, ϕ_i . Decision analysts meet with mission-area representatives and elicit their evaluations of the programs in their mission area. The representatives are given brief instructions; then they compare various combinations of the programs using the following criteria:

- o well-defined program(s);
- o clear requirement and concept of employment;
- o military effectiveness;
- o breadth of application;
- o current versus new capability;
- o readiness versus modernization;
- o proper program scheduling;
- o technical risk.

The necessary comparative judgments are simply "yes" or "no," answers that determine whether or not a set of one or more items has equal or greater value than another set.

The first task is to establish a rank-order of individual items in x_i so that

$$x_i^1 \succsim x_i^2 \succsim \dots \succsim x_i^m$$

with the superscript denoting the rank of the item in x_i . Then the analysts present a series of questions concerning preferences for combinations of items in order to narrow the interval (on the ϵ_i scale) which contains a given item. For example, we might find that $(x_i^2 \circ x_i^3) \succsim x_i^1 \succsim (x_i^3 \circ x_i^4)$, which implies that

$$\phi_i(x_i^2) + \phi_i(x_i^3) \geq \phi_i(x_i^1) \geq \phi_i(x_i^3) + \phi_i(x_i^4). \quad (4-1)$$

If we let $\phi_i(x_i^1) = 100$ be an arbitrary reference point, then $\phi_i(x_i^2) = 75$, $\phi_i(x_i^3) = 50$, and $\phi_i(x_i^4) = 25$ is one set of numbers that satisfies equation (4-1). Theoretically, if the axioms held and enough inequalities were stated, they could be solved for a unique ϕ_i . In practice, there is no need to elicit all the judgments necessary for a unique representation. An approximate representation is adequate. So, the group derives a few

inequalities and assigns numbers that satisfy the inequalities. The implications of any given assignment can be tested by assessing preferences for other combinations of items, and the numbers can be refined as the elicitation process evolves. (Techniques for questioning and assigning numbers are described in Section 4.3.2.2.)

After the individual mission-area scales, ζ_i , are constructed, they must be merged by a cross-scale. It would be possible to select one item from each mission area and produce one cross-scale ζ by eliciting the PEG's preferences for these items, but for practical reasons, the merging is done hierarchically. The mission areas are clustered by sponsor, and each sponsor produces a cross-scale that represents preferences for items from the mission areas within its cluster. All of the sponsors' cross-scales are subsequently merged by another cross-scale produced by the Program Evaluation Group. See Figure 2-1 for a display of the clusters.

The process for producing a cross-scale is the same at both the sponsor level and the PEG level of the hierarchy. First, we form a set Y by selecting three items--one high-, one medium-, and one low-priority item--from each cluster to present to the group of evaluators (PEG). This set, Y , is partitioned into a high-priority item subset, Y_H ; a medium-priority item subset, Y_M ; and a low-priority item subset, Y_L . Each subset is scaled separately by the PEG, and then the three scales are merged to produce one overall scale, ζ .

The three separate evaluations of items from one cluster or mission area allow the PEG's judgments about the ratios of value among the three items to be compared to the original judgments of the mission area committees (MACs). Formally, denote the three items chosen from

cluster i as x_i^H , x_i^M , and x_i^L . The comparison of PEG and MAC judgments can be made by checking the validity of the following:

$$\frac{\zeta(x_i^H)}{\phi_i(x_i^H)} = \frac{\zeta(x_i^M)}{\phi_i(x_i^M)} = \frac{\zeta(x_i^L)}{\phi_i(x_i^L)} .$$

where the numerators are the PEG scale values for the three subsets representing three priority levels. When the equality does not hold for items of a cluster or mission area, then the members of the respective committees convene to resolve the conflict and revise the scales to be compatible.

Figure 4-2 charts the progression of the scaling tasks: starting with a set of MC programs, X ,

- (1) Mission Area Committees construct scales, ζ_i ;
- (2) Cluster PEG's construct scales, ζ , by merging Missions into clusters;
- (3) MACs and cluster PEGs adjust their scales;
- (4) PEG constructs scale, ζ , for sample items from the clusters;
- (5) MACs, cluster PEGs, and the PEG adjust their scales; and
- (6) a scale, ϕ , is derived which reflects a priority order for all programs in X .

4.3.2.2 Single-scale assessment procedures - This section describes the procedures used by decision analysts to derive the benefit scales and $\phi_i \zeta_i$ for each mission area. We discuss several different approaches through the use of the following example.

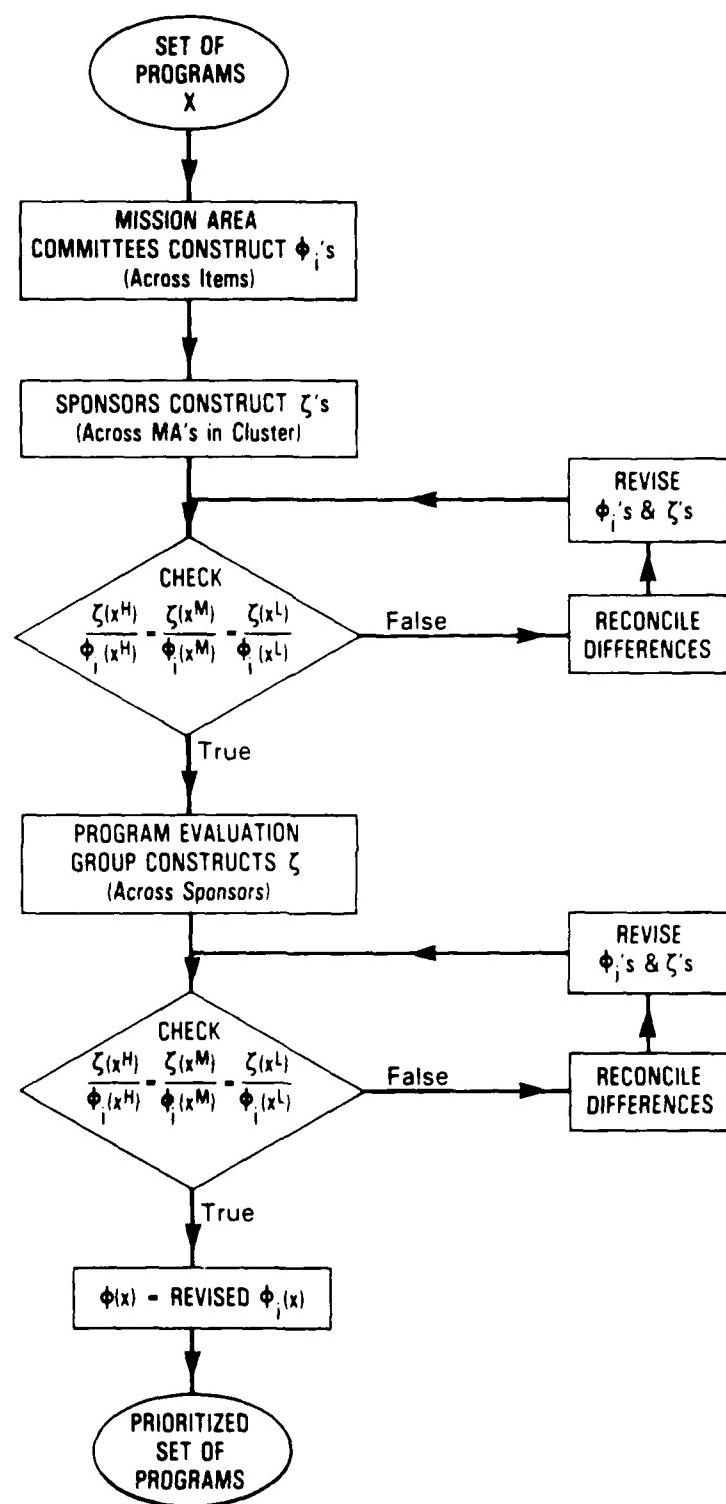


Figure 4-2
THE SCALING PROCESS

Suppose an analyst is assisting an MC committee with the scaling of nine items $X = A, B, C, \dots, I$. The group has already ranked the items in order of their value with respect to relevant criteria, and $A \succ B \succ C \succ \dots \succ I$. The analyst's task is to elicit the judgments of the group about the value of the items in such a way that a scale can be derived by the solution of a set of inequalities from the rules:

(i) If $x \succ y$, then $\phi(x) \geq \phi(y)$, and

(ii) $\phi(x \circ y) = \phi(x) + \phi(y)$. (4-2)

Top-down comparison questions - The primary method for constructing a benefit scale is by top-down comparisons of items and bottom-up numerical assignments. This approach is motivated by the belief that judgments about the comparative value of items are most easily made for items that are close in value. So, it is easier to assess the value of item B relative to item A, than relative to lower-priority items like G, H, and I.

The analyst presents the group with choices between individual items and combinations of items, beginning at the top of the rank-order with item A. Item A is compared to the combination of items B and C, and the group must decide whether they would prefer the purchase of A alone, or the purchase of both B and C. Suppose the group decides $A \succ (B \circ C)$. The analyst then makes the selection of A less attractive by offering B and C and D together versus A. Questions about A continue until an indifference point is reached, e.g., $A \sim (B \circ C \circ D)$, or the preference reverses, e.g., $(B \circ C \circ D) \succ A$. Suppose, on the other hand, that $(B \circ C) \succ A$. Then, the analyst makes the preferred side less attractive by offering B and D versus A, or C and D versus A. Again, the comparisons continue until an indifference point or a reversal is found. An interval about

$\phi(A)$ will be established by the implications of the representation model. For example, if $(C \circ D \circ E) \succsim A \succsim (C \circ D)$, then

$$\phi(C) + \phi(D) + \phi(E) \geq \phi(A) \geq \phi(C) + \phi(D).$$

In this process, note that it is the point of reversal or equality that establishes upper and lower bounds for $\phi(A)$ in relation to sums of $\phi(C)$, $\phi(D)$, etc. Once $\phi(A)$ is so bracketed, the next step is to establish an interval about $\phi(B)$, then $\phi(C)$, and so forth.

Numerical assignment - The ease of the subsequent numerical assignment will depend on the number of preference relations elicited and the tightness of the interval about each item. With respect to the latter criterion, the analyst should strive to bound $\phi(x)$ as narrowly as possible to reduce the size of the solution space. For example, the preference relation $(D \circ E \circ F) \succsim B \succsim (C \circ D)$ provides more information about $\phi(B)$ than does the relation $A \succsim B \succsim (E \circ F)$.

Suppose that in the example, the analyst elicited the following preference relations:

- (1) $(B \circ C) \succ A$
- (2) $A \succ (C \circ D)$
- (3) $B \sim (C \circ D)$
- (4) $C \succ (D \circ E)$
- (5) $(D \circ E \circ F) \succsim C$
- (6) $D \sim (E \circ F)$
- (7) $(E \circ F \circ G) \succsim D$
- (8) $E \sim (F \circ G)$
- (9) $(H \circ I) \succ F$
- (10) $(H \circ I) \succ G$

These relations are represented by inequalities in the model and can be solved for $\phi(A), \phi(B), \dots, \phi(I)$. In order to derive ϕ , we first fix the value $\phi(I)$ arbitrarily at 10. Then we determine the ratio of value between H and I by asking, "How many initiatives like I would it take to provide the same importance as H?" Suppose the response is 2, so that $(I \circ I) \sim H$, and $2 \phi(I) = \phi(H)$.

At this point, the inequalities implied by the relations can be solved, but not uniquely, for a set of scores. The equations and inequalities are:

- (1) $\phi(A) < \phi(B) + \phi(C)$
- (2) $\phi(A) > \phi(C) + \phi(D)$
- (3) $\phi(B) = \phi(C) + \phi(D)$
- (4) $\phi(C) > \phi(D) + \phi(E)$
- (5) $\phi(C) < \phi(D) + \phi(E) + \phi(F)$
- (6) $\phi(D) > \phi(E) + \phi(F)$
- (7) $\phi(D) < \phi(E) + \phi(F) + \phi(G)$
- (8) $\phi(E) + \phi(F) + \phi(G)$
- (9) $\phi(F) < \phi(H) + \phi(I)$
- (10) $\phi(G) < \phi(H) + \phi(I)$
- (11) $\phi(H) = 20$
- (12) $\phi(I) = 10$

The analyst still has a great deal of flexibility in assigning numbers that solve the inequalities, and one might reduce the solution space by presenting further comparison questions. Typically, however, one discovers the best comparison questions to ask by going directly on to the assignment of numerical values. The analyst relates the items' intervals of value that are implied by the preference relations, and the participants are asked to select the benefit values. In the example, we know that $20 < \phi(G) < 30$, and the group decides that $\phi(G) = 25$. Now, $25 < \phi(F) < 30$, and the group decides that $\phi(F) = 26$. $\phi(E)$ is calculated

to be 51, so $77 < \phi(D) < 102$. Here, the group has a wider range of values from which to choose, and decides that D is closer in value to E o F o G and assigns it a benefit of 100. Subsequently, they let $\phi(C) = 160$, $\phi(B) = 260$, and $\phi(A) = 300$. The resultant scale is:

<u>Item</u>	<u>ϕ (Item)</u>
A	300
B	260
C	160
D	100
E	51
F	26
G	25
H	20
I	10

The analyst uses the numerical scale to suggest new comparisons. For instance, two comparisons suggested by the above numbers are:

- (1) $(B \circ D) \succ A$, and
- (2) $D \succ (F \circ G \circ H)$, etc.

Direct adjustments to the values are made as a result of these questions, always making sure that ϕ satisfies the earlier judgments as well.

An approach for scaling long lists of items - A variation to the top-down approach to scaling is often used when the number of items to be scaled exceeds 15. In top-down questioning, the analyst presents a series of paired comparisons until an indifference or reversal point is found; whereas in the variation, the analyst directly asks the group to find the reversal point. Given that A is the first priority in a rank-ordered list of 20 items A through

T, the group is asked to examine the list in descending order and find the first two consecutive items x and y that give $A \succsim (x \circ y)$. If the selected items were I and J, the group is then asked to find the first two consecutive items w and z that give $I \succsim (w \circ z)$. This process continues until no more of these comparisons can be made.

The approach provides a simple way to start the scaling of a long list of items; it saves time by requiring fewer comparison questions. The result is a list partitioned by break-points that can be used to divide the items into smaller lists of about 10-15 items. Each list is scaled separately by top-down comparisons and bottom-up assignments, then quickly merged by using the preference relation that determined the break-point.

For example, suppose the list of 20 items A through T had the relations:

$$\begin{aligned}A &\succsim I \circ J \\I &\succsim L \circ M \\L &\succsim Q \circ R.\end{aligned}$$

The analyst can divide the list into two--A through K and L through T, and using the method described in the previous section, separately derive the following two scales:

<u>Item</u>	<u>\$ (Item)</u>	<u>Item</u>	<u>\$ (Item)</u>
A	50	L	95
B	48	M	90
C	47	N	80
D	45	O	62
E	42	P	60
F	40	Q	50
G	35	R	30
H	30	S	25
I	22	T	10
J	18		
K	15		

The two scales can be merged by observing that $I \succ L \circ M$ and testing a few other combinations such as:

$$\begin{aligned}L &\circ M \succ J \\J &\succ M \circ N.\end{aligned}$$

The above preference relations tell us that we can merge the lists by multiplying the first list, A through K, by the constant $\alpha = 10$.

A faster approach for experienced participants - If the group of experts has had previous experience in scaling, the process can proceed more quickly by allowing them to make direct numerical assignments. If they understand the properties of the representation model (in equation 4-2), they can place benefit values on the items directly without the aid of initial comparison questions.

The first item of a rank-ordered list is given a value of 100, and the other items are scaled relative to it. After the group makes the assignments, the analyst reviews several preference relations that are implied by the scale to check for consistency. The process of numerical assignments with checks by the analyst iterates until the participants judge the results to be accurate.

Special cases - There are some cases for which the analyst would have difficulty using the described top-down approach for elicitation and scaling, because the preference relations between single items and combinations do not give sufficient information about the scale. Two examples are:

1. the value of the top-priority item exceeds that of all other items combined (this is essentially a set-closure problem); and

2. all the items of the list are so close in value that the value of any two items exceeds the value of any one item; thus the analyst cannot find a lower bound for each $\phi(x)$.

The first case can be handled in several ways. The analyst can remove the excessively high-valued items from the set and scale the remainder by the regular method. Then he can try to identify the ratio of value between the high-valued item and the highest ranking item in the scaled list, and get, for example, $A \sim 100 B$. This type of ratio judgment is often difficult to elicit, so a precise numerical assignment is postponed until the next level of the scaling hierarchy (cluster PEG or overall PEG), where items of similarly high value from other mission-area sets can be compared.

For the second case, the analyst must present comparison questions about two or more items versus two or more other items in order to establish enough preference relations for numerical assignment. The value judgments are more difficult to make, and the resultant inequalities are more difficult to solve, so the analyst might opt to request direct numerical assignments and then check the results by using the multiple combination comparison questions.

Consistency/validity checks - Since the benefit scales, ϕ_1 , will undergo later revisions that are based only on samples from the sets X_i , it is very important at this stage for the analyst to ensure that the preference relations are consistent with the model's axioms and that the scale accurately reflects the elicited judgments.

Systematic tests for axiom violation should always be made during the elicitation of preference relations. When two or more items are synergistic or compensatory, the

group will have difficulty with comparison questions that involve these items, and they will most likely cite the existence of an interaction as rationale for a reluctance to make judgments. In such a case, the items are redefined or their elements are repackaged so that items that have inter-dependencies are grouped together as one program. (Other approaches to program packaging are described later in Section 4.3.3.)

The diagram in Figure 4-3 illustrates the in-process checks for consistency.

4.3.2.3 Multi-scale merging procedures - As described in the General Procedures part of Section 4.3.2.1, the PEG has the task of establishing a cross-scale that merges mission-area or cluster scales. The merging process begins after the mission areas have produced scales for their items, and the analysts and RPP have selected high-, medium-, and low-priority items from the mission areas or clusters. The items chosen to represent a mission area frequently include:

1. items that were controversial within the mission area;
2. items that had large benefit-values that could not be assessed by the mission area; and
3. two consecutive items from a mission area whose scale is characterized by two or three closely scaled groups of items (e.g., a scale that has five items with benefit values between 90 and 100, and five items with benefit values between 10 and 20).

The high-priority items are usually the top item in each mission area. The other items are chosen somewhat randomly

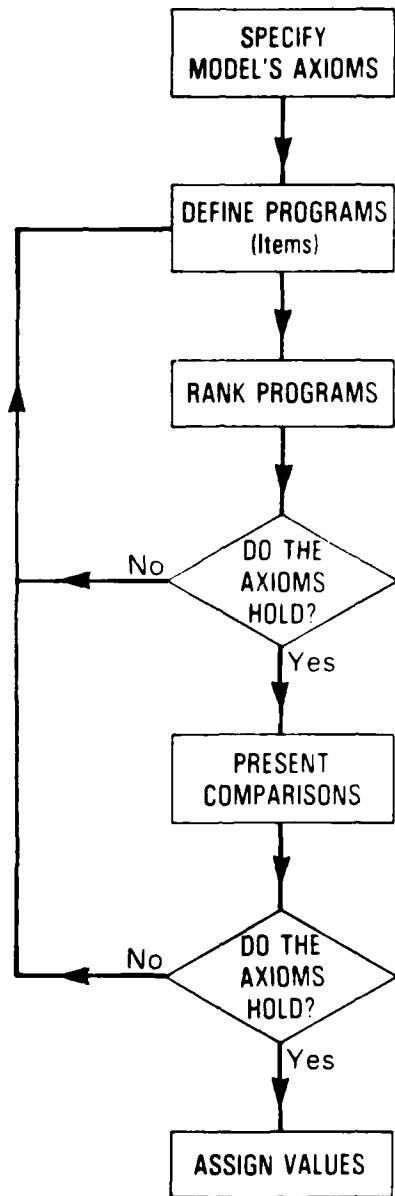


Figure 4-3
IN-PROCESS CHECKS FOR CONSISTENCY

from high, medium, and low segments of the scale with a preference for items that are well defined. These items are described in short briefings to the PEG by their proponents.

The PEG generally produces and merges three separate scales, one for the high-priority items (called the high cut), one for the medium-priority items (the middle cut), and one for the low-priority items (the low cut). These scales are usually derived by the top-down questioning approach; however, the difference between the PEG procedure and the mission-area committee procedure is that the PEG devotes considerably more time to rank-ordering and numerical assignment.

Rank-ordering - Each member of the group independently rank-orders the items of the cut under consideration, and then all the rankings are displayed. The areas of greatest conflict are discussed. For example, if one item from a ten-item list receives two individual ranks of two (second priority), and eight (eighth priority), then the individuals are encouraged to explain their reasons for the disagreement in ranking. Often, the cause for the conflict is a lack of knowledge of certain aspects of the programs. In such cases, more discussion about the items' characteristics will resolve the disputed ranking. After the major differences in rankings are discussed and information is exchanged, the individuals revise their rankings. The cycles of ranking and discussing differences continues until a group consensus is reached.

Scaling - By the time a final rank-order of items is established, the group will have a good understanding of the programs' merits, so they will have little difficulty in responding to the analyst's comparison questions for scaling. The analyst can use the typical approach of top-down questions and bottom-up assignments, or, as the group

becomes experienced in scaling, direct numerical assignments. In the latter case, the individuals will scale the ranked items independently and discuss the results and their differences, working towards a consensus in the same manner as the ranking procedure.

Merging the three cuts - After the three cuts are scaled, they are merged into one scale. The analyst asks the PEG to position the highest-priority item (or any other sample item) in the middle cut relative to the items in the high cut. For example, the sample item may be judged to fall between the seventh and eighth priority items of the high cut, and thus will have a benefit value in the range between their values. The analyst can derive the specific value from a few comparison questions, or allow the group to make a direct numerical assignment. The values of the other items in the middle cut are then multiplied by the ratio of the sample item's score in the high cut to the sample item's score in the middle cut. The low cut items are folded into the scale in the same manner.

Comparison of PEG scale and mission-area scales - The merging of the three cuts gives the ratios of value among the three sample items, x_i^H , x_i^M , x_i^L , from mission area i , as perceived by the PEG. The PEG's values are compared to the mission area's values by checking:

$$\frac{\zeta(x_i^H)}{\phi_i(x_i^H)} = \frac{\zeta(x_i^M)}{\phi_i(x_i^M)} = \frac{\zeta(x_i^L)}{\phi_i(x_i^L)} .$$

The equation fails to hold when the PEG judges the items to have ratios of values different from those perceived by the mission area. For example, the mission area may have assigned x_i^H , x_i^M , and x_i^L the values 90, 80, and 20, respectively, while the PEG assigned to them the values 75, 30, and 15.

Here, there is little difference between the ratios of x_i^H to x_i^L , but considerable disagreement about the ratio of x_i^H to x_i^M . (In some cases, the PEG might even reverse the items' order of priority.)

Disagreements are discussed and resolved during subsequent meetings of the PEG with each mission-area group. The groups exchange information about programs, and the analyst asks both groups to revise their ratios until a consensus is reached. (If the groups cannot agree, the PEG's scale takes precedence.)

Revision of mission-area scales - Once the PEG decides on the final values $\zeta(x_i^H)$, $\zeta(x_i^M)$, and $\zeta(x_i^L)$ for each mission area, the analyst revises the mission-area scales to reflect the final values, while striving to maintain (approximately) the original preference relations.

The translation of the original mission-area scale to a revised scale is shown pictorially in Figure 4-4. The values of the sample items are set equal to the final PEG values for those items. The revised values of all other items in the mission area are approximated by the graph of the line segments drawn between the sample points.

Since the PEG has evaluated the benefit of three items from each mission area relative to items from each of the other mission areas, the cross-scale is established and we can set ϕ (the final scale across all items in the POM) to equal the revised mission-area scale, so that for each mission area, i ,

$$\phi(x_i) = \phi'_i(x_i), \quad x_i \in X_i.$$

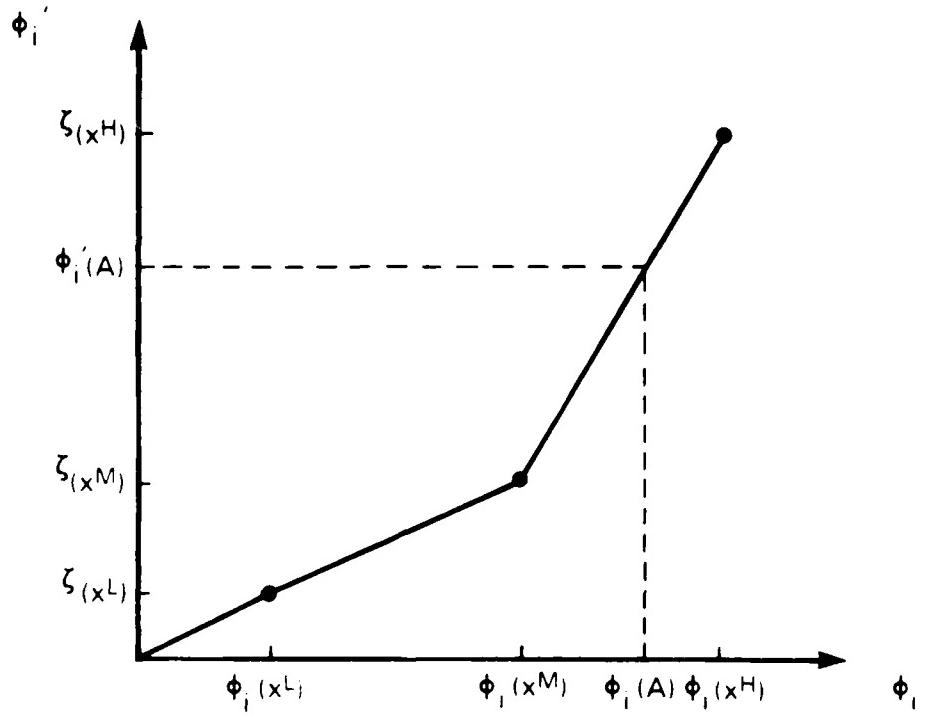


Figure 4-4
REVISION OF MISSION AREA SCALE

4.3.2.4 Integrated program packaging - Special cases exist for which it is difficult to design independent program initiatives that meet the restrictions of the model's axioms. Examples occur in the MC missions of tactical communications, command and control, and others. The axioms are violated due to interactions between programs; thus, the analyst has difficulty deriving benefit scales. Dependencies exist because these missions are accomplished through systems and networks with elements like links in a chain. It is combinations of these elements that provide value, not the independent elements themselves. For instance, upgrading a radio transmitter alone has little value if the new transmitter will not function with the existing receivers. The communication system must have an integrated, not piecemeal, upgrade.

When independence of items cannot be assumed, yet a program for operating or acquiring the items must be developed, then the items are packaged together into a logical set of system initiatives. The first initiative in the set is a "bare bones" improvement to the existing system. The next initiative is a fully integrated, system enhancement of the bare bones initiative. The third initiative is an enhancement of the second, and so forth. Thus, one defines a set of integrated, executable, staged enhancements of the status quo system, extending from "bare bones" to "gold-plated." Their costs are successively greater, and they provide successively more capability. A diagram of the structure of a set of system initiatives is shown below. It shows the first step to be a bare bones system with three potential enhancements.



These system initiatives are different from the other POM initiatives because they build upon one another in a staged fashion. This means they are not independent of each other. However, they are designed in such a way that their costs and benefits are additive to one another just like those of other initiatives. Consequently, for purposes of programming, they can be prioritized by scaling their benefits as if they were independent of one another. Thus, the individual levels enter the benefit scaling process separately and are scaled in the same manner as all other items. However, the prioritization of items by benefit scaling will preserve the staged order of the initiatives only if the incremental benefits of the stages are decreasing in value, that is:

$$\$ (\text{BAREBONES}) > \$ (\Delta 1) > \$ (\Delta 2) > \$ (\Delta 3).$$

This is usually true because a sponsor will structure the system to provide the most beneficial enhancements first.

In addition, if the overall POM list is ordered by cost-benefit ratios of items, the incremental cost-benefit ratios of the stages must be decreasing. Again, the sponsor will most likely structure the system in a cost-effective order.

4.3.3 Conducting the preference assessment meetings - The entire POM scaling process, as depicted in Figure 4-1, occurs during a series of meetings among the analysts and USMC groups. This section outlines the sequence and the management of the meetings.

4.3.3.1 Mission-area committee (MAC) meetings - In the first stage of the process, the objective is to survey and document USMC needs at the mission-area (MA) level. The vehicle for communicating the value judgments of the MAC's is the MA benefit scale. The decision analysts

assist the MAC's in developing their scales during sessions with each committee. The strategy of each session is, first, to provide instruction about the scaling procedure with emphasis on the committee's task requirements and, second, to develop the scale using the tactics previously described.

The development of the scale starts with the rank-ordering of the items, followed by comparison questions and numerical assignments. The ranking and scaling tasks encompass the task of packaging programs to ensure the validity of the representation model's axioms. That is, repackaging occurs, as needed, during the ranking and scaling.

The meeting is directed by the analyst, who asks questions, allows discussion by the group members, and then requests responses. Some problems that arise in eliciting judgments are:

1. The group judges a program to be immeasurable.
2. An officer wants to use objective data as a basis for measurement in place of subjective judgment.
3. An officer will not express his judgments independently of his General's.

The first issue was briefly discussed in Special Cases. The analyst should not try to measure the value of a program that seems to be much greater in value than all the other items. The program can be set aside for consideration by the PEG. However, the mission-area committee should be encouraged to input some quantitative information so that their judgments can impact the final POM results.

The second problem is a common one that occurs when the officers are not accustomed to the methodology. Objective data can be incorporated into the judgments, but should not be relied upon as the sole basis for judgments since they never encompass all the important aspects of a program's benefit value.

The third problem can only be handled by emphasizing the objective of mission-area scaling: the group's task is to determine MC program needs based on individual officer expertise, whereas the emphasis at the next level of the hierarchy (general officers) is to adapt USMC needs to programmatic and government-wide considerations.

The mission-area committee then briefs the content of three items to its PEG, which subsequently produces a cross-scale. The PEG's objective is to determine the trade-offs among items across the respective mission areas. If necessary, the PEG calls upon mission-area committee members to provide information and clarify points about their programs.

The PEG cross-scaling terminates only when scaling conflicts with the mission area committees have been resolved.

3.3.3.2 PEG meetings - The mission-area representatives brief three items each to the PEG to be used as elements for the evaluation of the cross-scale. The PEG's perspective in assessing program value differs from that of previous levels, as the PEG is concerned with a wider range of priorities and must compare widely divergent interests such as Tactical Communications and Supply/Maintenance.

The analyst's strategy in conducting the meeting is to explain the procedure, and for each of the

three cuts, (1) obtain a rank order, (2) present comparison questions, and (3) assign numerical values. As mentioned before, the scaling at the PEG level requires discussion and compromising until a consensus is reached.

Reaching a consensus is often difficult, but the participants usually revise their judgments as information is exchanged. When single uncompromising members appear, their dissenting votes are recorded, but progress is not halted to accommodate extreme viewpoints. There is sometimes a tendency for the group to accept a majority vote on an issue, but the analyst should instead encourage discussion until there is more agreement.

The final step of the procedure is to reconcile PEG cross-scale and mission-area scale differences. Members of both groups convene to revise judgments about the sample items. Then the analyst revises all mission-area scales to reflect the changes.

The product is a list of all items that can be ordered by overall benefit.

4.3.4 Cost-benefit analysis - The overall benefits of the program initiatives provide a basis for comparing the cost-effectiveness of the initiatives. This section describes the MC's technical approach and procedures for analyzing cost-effectiveness during POM preparation. Their strategy for using cost-benefit analysis is discussed in Section 2.4.2.3.

4.3.4.1 Technical approach - The overall benefits of the initiatives provide a single numeraire for comparing their importance. To compare their cost-effectiveness, another numeraire is needed to represent their relative costs. In the MC's approach, the cost numeraire of an initiative is defined as the sum of its resource requirements measured in constant

dollars over the five program years of the POM. This is an adequate measure of cost to identify large differences in cost and cost-effectiveness among initiatives. It is a simple numeraire to compute since the MC sponsors provide cost estimates in constant rather than escalated dollars. It is an objective numeraire since the cost estimates are validated by the MC staff during the POM process.

Given numeraires for both the benefits and the costs of the POM initiatives, one may compare their cost-effectiveness in two ways. First, the ratios of benefit to cost will show which initiatives offer the most value per dollar of resource spent. For a fixed total of dollars to spend, it would be better in theory to spend them on initiatives offering high value per dollar rather than on initiatives offering low value per dollar. This suggests the procedure of listing the initiatives in order of decreasing cost-effectiveness and then programming as many items as possible from the top of the list. Such a list is prepared during POM development.

A second method of combining the cost and benefit numeraires is to compute a "net benefit" for each initiative. This is done by subtracting a fixed multiple (K) of the cost from the benefit. The formula is:

$$\text{Net Benefit} = \text{Benefit} - K \times \text{Cost}$$

The initiatives are then listed in order of net benefit, which indicates another theoretical order for programming them. By selecting the multiplier K to present the trade-off between benefit and cost--that is, the benefit-cost ratio that is just acceptable to the MC in light of its anticipated budget--the net-benefit list will provide a cost-effective prioritization.

The net-benefit approach has the drawback that one must guess at the right value of K. However, this drawback can be the method's strength, too. By varying K from zero to infinity, one can produce prioritizations that put more and more emphasis on cost-effectiveness, ranging from none ($K = 0$) to complete ($K = \infty$). Thus, one can explore a range of emphases.

Another strength of the net-benefit approach over the ratio approach is that it produces a more acceptable ordering of initiatives that are close in ratio but far apart in benefit and cost. The large-benefit initiatives will occur first in the list. This is a more natural, easily understandable ordering.

4.3.4.2 Procedures - The POM-DBMS provides RPP with the capability to produce lists of initiatives that are ordered by benefit, cost, cost-benefit ratio or net benefit. For reasons discussed in Section 2.4.2.3, the basic list used by RPP and the PWG is the benefit-ordered list. The other lists are used chiefly to look for initiatives that are either "padded" with nonessentials or "under-resources."

5.0 SUMMARY AND CONCLUSIONS

5.1 The Marine Corps

This report has described the decision-analytic methodology used by the MC in its programming system as of June 1980. The methodology has been presented from the point of view of the decision analyst who supports the RPP staff. It provides a working knowledge of the methodology, not merely overviews. It progresses from a general description of DoD PPBS to describe (1) the broad features and concepts of MC programming; (2) the MC's strategy and guidelines for the prioritization phase of programming; and (3) the decision-analytic concepts and procedures used for MC prioritization.

The MC's green-dollar POM 82 submission, the most recent product of the methodology described here, was accepted at the Chief of Staff's Committee without demur from the sponsors. Thus the methodology helped the MC achieve, for the first time, the ideal of developing a program from action-level staff inputs that its senior staff could agree to without the need for further debate.

5.2 Transferring the Technology

We believe that the MC's success with their programming system merits wide consideration by the other military services and by other government agencies. Given the unique character of each service and agency, it is unlikely that any would or could choose to simply adopt the MC system. However, all might find aspects worth incorporating as they develop their own systems. Even if an institution's programming system is altogether different from the MC's, the MC's core decision-analytic strategies and techniques for assessing and combining staff judgments can be put to use.

For instance, the MC application aims at priority programming, but we believe that many of the same methods can be applied to multi-level programming systems (e.g., DoD and CNO programming) to collect and combine staff judgments. In this case, the judgments would be used to determine the fiscal and programmatic guidance that initiates programming for the program sponsors.

Many agencies outside DoD and program sponsors within DoD may be able to apply the MC system with only small modifications if they are similar to the MC. Four important features of the MC reflected in their programming system are as follows:

1. The MC is an organization oriented towards improving its capabilities to serve when needed. All of its programming is oriented towards its capabilities to perform its missions.
2. While the MC's contingencies include many different scenarios, its major missions in those scenarios are essentially the same, and it has fewer missions to consider than the other services. This is not true of the larger services; e.g., the Air Force needs different equipment and performs different missions for Europe than for Korea. Thus, MC programming is not complicated by the necessity to balance off capabilities that would contribute to a wide range of scenarios in a very wide range of missions.
3. The MC staff is small enough to allow rapid, accurate coordination and communication at all levels. This makes successful programming, which touches the whole staff, more achievable than it may be in the larger military services.

4. The MC sponsors themselves develop the great majority of items that compete for a place in the MC POM, whereas a multiplicity of field/fleet commands develop a large fraction of the items that compete in the other services' POMs. The MC headquarters staff is likely, therefore, to have a clearer sense of priorities among items than the other services' headquarters staffs. All else being equal, this should make good programming easier for the MC.

If an institution shares such features with the MC, the MC system may be a good match to its programming requirements.